BRNO UNIVERSITY OF TECHNOLOGY
FACULTY OF CIVIL ENGINEERING

AdMaS®
ADVANCED MATERIALS, STRUCTURES AND TECHNOLOGIES

Annual Report on the Activities of the AdMaS Centre 2019

Foreword

Dear Colleagues,

You are getting into your hands the results of the AdMaS Center for the year 2019. It was the last year of AdMaS project sustainability and another year in which the planned outputs were successfully met.

All acquired devices were fully used to fulfill the milestones set at the beginning of the project. It is very gratifying that the basic idea of building a versatile Center in the field of construction, which fully integrates the knowledge from individual fields of research activity – material, constructional, technological and environmental – has been fulfilled. The year 2019 was successful in terms of administration and fulfillment of the volume of contract research. The AdMaS UP NPU I project from the National Sustainability Program for 2015–2019 was the last major support of the Center's operations. In the next period, we will have to do without it.

We will partially try to replace it with the National Competence Center from TA CR programs, which the AdMaS Center managed to acquire as co–beneficiary. In 2020, this project will partially compensate for earlier funding from the AdMaS UP NPU I project.

I would like to thank beforehand to all those involved for fulfilling the monitored sustainability indicators without problems during the entire sustainability of the AdMaS project.

The Academic Senate of the faculty of Civil Engineering of Brno University of Technology approved the new Statute of the AdMaS Center, which also includes a modified organizational chart in the structure of the faculty. From the beginning of year 2020, processes will be set up to respect this new status. Of course, the “AdMaS” brand will remain, and the results of contract research projects and other economic activities will continue to be reported under the AdMaS Center. Similarly, R&D projects will continue to use the Center's facilities and equipment.

Today, the AdMaS Center is a highly sought after and reliable partner for many collaborating companies and offices. The Faculty of Civil Engineering has acquired in AdMaS Center a modern workplace that is one of the best–equipped scientific and technical facilities in the field of construction in Europe. It is up to us how we will now take advantage of this technological lead and further develop it.

Once again, I thank everyone for their work so far. I would like to highlight, in particular, the leaders of the research programs and the leaders of the research groups, ie those who will no longer continue in their positions due to the change of status. I believe that the next period will be a continuation of both the long–term successful journey of the AdMaS Center and the Faculty of Civil Engineering of the Brno University of Technology as well.

Prof. Ing. Miroslav Bajer, CSc., Dean

Contents

1. Organizational structure

Headquarters

Head of the Center	Ing. JUDr. Zdenek Dufek, Ph.D.
Scientific Director of the Center	Prof. Ing. Drahomir Novak, DrSc.
Deputy Director, Financial Manager	Ing. Zdenek Krejza, Ph.D.
Deputy Director of the AdMaS UP project	Assoc. Prof. Ing. Tomas Apeltauer, Ph.D.
Administrative Manager	Assoc. Prof. Ing. Jiri Zach, Ph.D.
Lawyer	JUDr. Sylva Pochopova
Facility Manager	Ing. Michaela Ulbrychova
Economist and Coordinator of International Projects	Ing. Vilem Paril, Ph.D.
Secretary	Zlatuse Dokoupilova

International Scientific Board

Professor Harald Garrecht (Chairman) – University of Stuttgart, Germany

Professor Garbacz Andrzej, Ph.D. D.Sc. – Warsaw University of Technology, Poland

Professor Humberto Varum, Ph.D. – University of Aveiro, Portugal

Assoc. Prof. Dr. Andrea Giusepe Capodaglio – University of Pavia, Italy

Assoc. Prof. Dr. Alfred Strauss – University of Natural Resources and Life Sciences, Vienna, Austria

Supervisory Board

Ing. Jaroslav Bures, CSc.

Assoc. Prof. Ing. Ladislav Janicek, Ph.D., MBA

Ing. Pavel Krejci

Ing. Jiri Slama

Ing. Oldřich Sasinka, MBA

Research Programme RP1: Development of Advanced Building Materials

Head of Programme	Prof. Ing. Rostislav Drochytka CSc. MBA, dr.h.c

Technology of Building Materials Research Group

Head of Research Group	Assoc. Prof. Ing. Jiri Zach, Ph.D.

Microstructure of Building Materials Research Group

Head of Research Group	Assoc. Prof. Ing. Jiri Bydzovsky, CSc.

Research Programme RP2: Development of Advanced Structures and Technologies

Head of Programme	Prof. Ing. Jan Kudrna, CSc.

Structural and Transport Engineering Research Group

Head of Research Group	Assoc. Prof. Ing. Pavel Schmid, Ph.D.

EGAR Research Group

Head of Research Group	Prof. Ing. Petr Hlavinek, CSc. MBA

Mathematical Modelling Research Group

Head of Research Group	Prof. Ing. Drahomir Novak, DrSc.

2. Activities in the area of Center Management and Organization

The third monitoring report from the sustainability period, which was approved by the managing authority in December 2019, was elaborated at the end of January 2019.

Throughout the year, in line with the recommendations of the international evaluation, several joint horizontal integrations of research teams and meetings of R&D workers across research groups and work/scientific ranking took place. The Center was involved in few promotional events such as *Scientists' Night*. Furthermore, elements of HR policy, introduced in previous years, such as supporting young researchers and promoting communication across AdMaS Research Groups, have been applied. As every year, in 2019, a number of domestic and foreign guests from various areas of industry and education visited the Center (see Chapter 3).

In accordance with the technical annex of the project, the Management of the Center has actively applied the principles of Human Resources Policy. These included regular evaluation of R&D personnel, personal and motivational interviews with the staff of the Center, support for new projects and the Center management mobility. In addition, regular monthly meetings of the management of the Center were organized with the participation of representatives of individual RP and RG.

Mobility of employees abroad (in all R&D categories) and internships of foreign workers in the AdMaS Center continued in year 2019 as well. The Center held many seminars and training courses for application sphere workers. There was also active cooperation with the application sphere, both in the area of contractual research and in the area of applied R&D projects.

On March 15, 2019, there was a Center staff meeting associated with the presentation of results from 2018 and unveiling plans for future years.

The Supervisory Board of the Center held a meeting on June 11, 2019. From September 25 till 27, 2019 AdMaS Center International Scientific Council met, during which the foreign experts evaluated the Center's operations for 2019 as excellent.

3. Seminars, events, presentations

From the point of view of the activities of the whole Center in 2019, the following were:

- At the beginning of January 2019 the AdMaS Center welcomed another Brazilian trainee, Giulia Tomazi Kny. Giulia comes from Porto Alegre and is a bachelor's student at the Federal University of Rio Grande do SUL. She joined the AdMaS Center as part of a program of academic internships for Brazilian students at research Centers of Czech universities, organized by the Institute of Czech–Brazilian Academic Cooperation INCBAC. Giulia was involved in the project *Optimization of Granulometry of Fine Surfaces in Concrete,* under the leadership of Professor Hela, a member of the Technology of Building Materials Research Group.

- On February 18 and 19, 2019, RG EGAR took part in an excursion to the WWTP Linz – Unkel near Bonn, Germany, along with colleagues from Mendel University of Agriculture and Forestry in Brno and ZERA agency. At this wastewater treatment plant operates an unique equipment belonging to company PYREG, which enables pyrolysis treatment of sewage sludge. The aim of the excursion was an exchange of contacts and experience in the operational application of technology, the possibility of comparing legislation in the times when the Czech Republic is currently making decisions how to solve the future treatment of sewage sludge, and the so–called German route is one of the options. RG EGAR received examples of a carbonaceous product that can be compared to their own development.

- On February 21 and 22, 2019, two Lithuanian colleagues from the Technical University of Kaunas visited the Faculty of Civil Engineering and the AdMaS Center. Assoc. Prof. Karel Dvorak, Prof. Rudolf Hela and Assoc. Prof. Lenka Bodnarova took up the guests on the excursion through the Center, the accredited testing laboratory was then represented by Ing. Adam Hubacek. The director of Research Centers for Building Materials and Structures, Ernestas Ivanauskas, and the Project Manager, Audrius Grinys, expressed interest in close cooperation in the field of concrete and concrete research and further in the field of building materials microstructure.

- AdMaS representatives attended an event organized at the Ministry of Industry and Trade on February 26, 2019, called the *BIM 2022 concept*. The aim of this event was to introduce the key actors with the process of introduction of BIM technologies in the Czech Republic. AdMaS activities were presented by the director, Dr. Zdenek Dufek. Among other things, he provided information on the BIM Lifelong Learning Course, on the development of the use of BIM models as a basis for the creation of evacuation models of people and smoke places and on a project that the Center will address within the CAMEB National Competence Center aimed at connecting virtual reality and BIM.

- On March 11, 2019, the Povodi Morava held its regular meeting in the AdMaS Center. Before the begining, the Technical and Operational Director, Ing. David Fina, and CEO, MVDr. Vaclav Gargulak, met with the director of the AdMaS Center, Dr. Zdenek Dufek, and discussed the areas of possible cooperation. This was followed by a presentation of the Center, a meeting and an afternoon tour of individual laboratories.

- AdMaS management convened a traditional staff meeting on March 15, 2019. The results of the AdMaS project for 2018 were presented by the director, Dr. Zdenek Dufek and the Dean, Prof. Miroslav Bajer. Prof. Novak informed the participants about the rules of the AdMaS UP project for 2019. The employees were also get acquainted

with the project of the National Competence Center CAMEB and with the preliminary plans for the following years, when the Center expires the sustainability period.

- In the period from March 11 till 22, 2019, a Russian student from the Kalashnikov Izhev State Technical University, Aleksandr Gumenyuk, took an internship at the AdMaS Center. As part of this internship, he worked on his thesis on extending durability and optimizing the mechanical properties of sulfur–containing cementitious composites. During the internship he used mainly computer tomography and scanning electron microscopy to study the microstructure of developed materials.

- Two PhD students, Ing. Pavel Sperka and Ing. Jiri Sach, who are working on research projects in the AdMaS Road Laboratory, attended the international conference *Celebrating 20 Years Road Materials and Pavement Design* at the end of March 2019. The conference was held in Lisbon, Portugal and featured the best contributions from the RMPD scientific journal on road construction materials. During the conference, they managed to make contact with professor Ana Chistina Freire from Portugal, who deals with the testing of reinforced asphalt strata with glass and carbon fiber gratings. Furthermore, negotiations were held with professor from Krishna Prapoorna from India, who is also involved in the development and testing of asphalt mixtures with asphalt modified with tire rubber (crushed old tires).

- The expert team from FCE assisted in cases of serious violations of the static state of buildings during the spring 2019 of the Brno City Hall. For example, they focused on the Luzanky Leisure Center. The council approved the agreement on free cooperation between the city and the university, resp. the AdMaS Center. The output of the cooperation will be, in addition to the necessary effective proposals for suitable construction measures, also joint professional publications or contributions at conferences.

- On April 1, 2019, the Director of the AdMaS Research Center, Dr. Zdenek Dufek, attended the international professional conference *Inland Navigation for the 21st Century*, which took place in Prague. In his reading he informed about the progress of the Research Center project focused on the design of technical regulations for the safe construction and operation of LNG refueling stations.

- From April 2 till May 29, 2019, Ekaterina Karpova, a student of the Vilnius Gediminas Technical University (VGTU), worked at the Center as part of the Erasmus + program. The student was interested in the influence of multilayer carbon nanotubes (MWCNTs) on the properties of cement mortars and concretes with various types of superplasticizers. In her experimental work she used mainly scanning electron microscopy (SEM) and porosimetry (MIP).

- On April 2, 2019, an excursion for students from the Institute of Forensic Engineering took place in the AdMaS Center. The excursion was focused mainly on the influence of different pavement surfaces on the anti–skid properties of pavements and their testing. Students were also acquainted with the main testing facilities available in the Center.

- On April 10 and 12, 2019 an excursion of secondary school students, namely the Secondary Technical School of Chemistry in Brno and the Secondary School of

Industrial and Art in Hodonín took place at the AdMaS Center. The students got acquainted with the laboratories and instrumentation and could also try to prepare asphalt mixture sample.

- On April 15, 2019, students from the College of Industry and Construction in Decin visited the AdMaS Center. The excursion was focused on traffic constructions and testing of materials used for these constructions. Students looked at the rail grate and other materials used for the construction of railways that are located in Hall H. Then they visited the Center's road laboratory.

- On April 17, 2019, FCE organized a lecture of the Governor of the Czech National Bank, Ing. Jiri Rusnok, on the topic *"The role and tasks of the Czech National Bank, including current challenges in monetary and macroprudential policy"*. After the lecture, the Governor visited the AdMaS Center, where he was acquainted with the premises and research projects and goals by the Center Director, Dr. Zdenek Dufek, and his deputy, Dr. Zdenek Krejza.

- On April 25, 2019, AdMaS students attended *Conference of Student Chambers of Faculties of Civil Engineering (KOSTAF)*, organized by FCE. Students were guided through the laboratories of the Center and acquainted with the equipment.

- Head of the research program Development of Advanced Building Materials, Prof. Rostislav Drochytka, and the director of the AdMaS Center, Dr. Zdenek Dufek, visited the Izhevsk State Technical University of M. T. Kalashnikov in Russia in the last week of April, 2019. The aim of the trip was to develop cooperation in the development of new electro–conductive composites for wide use in the construction industry using various types of secondary raw materials in the form of admixtures into composite materials. The possibility of opening international double degree studies in doctoral study programs was also discussed.

- The AdMaS Road Laboratory was during production of new asphalt mixtures involved also in the use of R–material – a material obtained from an old asphalt pavement. A student of the 4th year of the Faculty of Civil Engineering, Karel Spies, within his Bachelor thesis proposed and tested a new type of asphalt mixture with a higher content of R–material and with asphalt content modified with rubber granulate obtained from old crushed tires. In laboratory tests, he made full use of the AdMaS equipment. The proposed asphalt mixture was used in mini–test section at a very busy intersection of Veveří and Pod Kaštany streets. The student with his thesis won the faculty round of Student Scientific and Professional Activities (SVOČ).

- On Tuesday, May 14, 2019, with the participation of the Dean of FAST, prof. Miroslav Bajer, the 11th meeting of the Scientific Board of BIC Brno took place in the AdMaS Research Center. The main guest of the meeting was the chairman of the Technology Agency of the Czech Republic, Prof. Petr Konvalinka, who discussed with the present members mainly news in support of applied research. At the beginning of the event, the director of the AdMaS Center, Dr. Zdenek Dufek, presented the research programs of the Center. The presentation continued by Dr. Petr Pracna's speech – member of the Technology Center of the Academy of Sciences of the Czech Republic – who introduced opportunities for construction field in the HORIZON 2020 program. Ing. Karel Kouril, Ph.D., member of the Council for Research, Development and Innovation,

spoke about the Innovation Strategy of the Czech Republic in 2019 – 2030. After the council was finished, guests visited the premises and laboratories of the Center.

- In the week from May 20 to 24, 2019, Assoc. Prof. Hector Cifuentes Bulte from the University of Seville, Spain was a guest at the Institute of Structural Mechanics, with the support of the Internationalization Project and the Institute of Physics of Materials of AS CR, v.v.i. Assoc. Prof. Cifuentes is an eminent expert in describing the behavior of building materials with a focus on concrete with scattered reinforcement, including fracture–mechanical aspects of their response to both static and dynamic loading. The guest was interested in the activities of the Mathematical Modeling Research Group with an emphasis on numerical simulations of structural stresses using experimental data and on the functionality of the methodology of complex analysis of building elements based on cement composites. The main focus of the Assoc. Prof. Cifuentes's stay was deepening of exclusive international contact, consultations with faculty academics and doctoral and master students, consultations on joint and planned experiments, preparation of joint publications etc.

- On June 3, 2019, researchers from the AdMaS Center, led by Prof. Kudrna and Prof. Stastnik, made a diagnosis of the sealing shell of the tank at Dlouhe Strane. This reservoir serves as a part of the pumped storage power plant Dlouhe Strane. A visual inspection of the state of the art was carried out on site, and locations for core boreholes, which will be examined further, were identified,

- A team of experts from BUT, headed by an AdMaS employee, Dr. David Beckovsky, technically participated in the preparation of pilot subsidy programs for water retention and drought prevention, green roofs and the construction of rainwater retention tanks in the city of Brno.

- From May 28 till June 5, 2019 the traditional Field Training was held in Stare Mesto pod Sneznikem, which is intended for all students of the 3rd year of the bachelor's study program Construction and Transport Structures. The teaching was organized by the Institute of Railway Structures and Constructions in cooperation with the Institute of Roads and Institute of of the Faculty of Civil Engineering, Brno University of Technology. Some of the AdMaS researchers also participated in the lessons. The Center's equipment – measuring trolley KRAB was used in the course. The students also took part in an excursion to the pumped storage power plant Dlouhe Strane, where the condition of the tank shell was being diagnosed. Prof. Kudrna acquainted the students with details regarding the construction of the tank shell and asphalt mixtures used here.

- On Wednesday, June 5, 2019, an excursion of the Brno Secondary Technical School of Construction took place in the AdMaS Center. The Center was visited by more than 70 students with pedagogical accompaniment. The guests went through a testing laboratory and a road laboratory in the P1 building and a laboratory of geotechnics and a laboratory of geodesy at P4.

- In July 2019, employees of the Microstructure of Building Materials Research Group conducted a local survey to assess the quality and degree of degradation of concrete in the Kunovsky Forest barrage. In situ inspection of the hydraulic structure was performed and during this inspection concrete samples (core drilling) were taken. Also, the depth of carbonation including acoustic tracing was determined. In accordance with

the customer's requirements, test specimens were prepared from the cored boreholes for the determination of physical–mechanical parameters, as well as samples for the analysis of chemical and phase composition with respect to the determination of the quality and degree of concrete degradation.

- On September 3, 2019, Czech Television presented in its program *"Events in Regions (Brno)"* a reportage called *"Shelter from Waste"*, where the audience got acquainted with an interesting student project *Plastic Crystal*, in which the staff of the Microstructure of Building Materials Research Group helped students with processing of recycled plastics into cladding elements for shelter.

- On September 4, 2019, an excursion for participants in the energetics course took place at the AdMaS Center, with the target group being young employees under 35 years of age. They learned how to uncover energy saving reserves, optimize processes or implement energy–saving measures in the company, thereby contribute to better climate protection. The organizer of the event, the Czech–German Chamber of Commerce and Industry, chose the AdMaS Center not only with regard to its current activities in the area, but also to the technical and technological background of the Center. Employees of the EGAR Research Group, Dr. Tomas Chorazy, Dr. Miroslav Cekon, Dr. Jakub Racek, and Ing. Kristyna Velikovska, gradually presented the activities of the Center in the field of alternative energy use and guided the guests through the AdMaS Center during the practical part of the training in the *Young Energy Europe project*.

- On September 4, 2019, within the ongoing cooperation of the AdMaS Center with CIDEM Hranice, a.s. were prepared and subsequently tested test specimens of cement–bonded particleboards with respect to assessment of physical–mechanical parameters, microstructure and analysis of combustion heat. The ensembles were manufactured in laboratory. Significantly modified formulas were used for the production of plates, with a view to achieving lower bulk density and improving fire resistance while maintaining minimum standard requirements for utility properties.

- In August 2019, the Center welcomed two foreign trainees to the road laboratory. On August 6, 2019, arrived French student Arnaud Chuter, who is studying civil engineering at the EI.CESI University in Angoulême, specializing in transport construction. The other student was Riko Sakuda, who came from Japan thanks to the IAESTE organization. Riko studies at YNU University in Yokohama, her main specialization is urban communications and urban infrastructure.

- On 16 September, 2019, the AdMaS Research Center welcomed members of the Bosnian delegation. An excursion mapping the activities of the Center in the field of urban engineering with an emphasis on water management infrastructure and geotechnics was prepared in cooperation with GEOtest, a.s. During the excursion, interesting contacts were exchanged and common topics discussed with the Dean of the Faculty of Mechanical Engineering of the University of Zenica, Prime Minister of the Canton of Zenits–Doboj, Director of the TRA Agency for Tesanj Municipality Development and other delegation participants.

- Employees of the Technology of Building Materials Research Group attended the *IVIS 2019 International Conference (14th International Vacuum Insulation Symposium* in

Kyoto, Japan) from September 19 to 20, 2019, where they presented new findings from the research team in the field of vacuum insulation development (VIP). Part of the meeting was an annual meeting of the *Association for Vacuum Insulation Panels VIPA International*, of which has been BUT and the AdMaS Center a member since 2018.

- On September 19, 2019, the Mathematical Modeling Research Group along with the Institute of Geonics AS CR, v. v. i., namely to Dr. Leona Vavro and Dr. Martin Vavro, welcomed an important expert in the field of rock fracture testing, prof. Yuzo Obaru from Kumamoto University, Japan. In this day of the 120th anniversary of founding of BUT prof. Obara presented his lecture in the Institute of Structure Mechanics meeting room and then visited the premises of the AdMaS Center.

- From September 24 till 27, 2019, the last International Scientific Council of the AdMaS Center was held. During their stay, the board members took part in the celebrations of the 120th anniversary of the foundation of the Faculty of Civil Engineering and in the evening performance Night at Karlstejn in the Brno City Theater. Both the AdMaS Center and the Faculty held meetings with individual research groups for two days, with representatives presenting their achievements and ideas for 2019. At the end of the week, the Center's staff said goodbye to the board members and thanked them for their support, motivation and very friendly, yet professional, relationships.

- On September 27, 2019, in the evening, the AdMaS Center opened to visitors of the popular event *Scientists' Night*. This year theme was Considering the Planet. The staff of the individual laboratories, in collaboration with students and family members, prepared several sites reflecting the current research. They prepared a demonstration of interesting devices for the visitors, explained their use and attracted two hundred guests in the form of a competition or a practical demonstration. The most popular equipments were, as in previous years, 3D printer products, a competition with a tomograph, a drone simulation, Liebherr car games and, of course, the actual production of a roadway sample from an asphalt mix. An electric car from E.ON also had a great response. Both young guests and their accompaniment gained not only new knowledge, but also received many ecological souvenirs.

- On October 1, 2019, the General Meeting of the CAMEB National Competence Center was held at the CTU in Prague. The meeting was opened by the Chairman of the Board, Assoc. Prof. Lukas Ferkl, who welcomed the present chairman of TA CR, Prof. Petr Konvalinka. A presentation of the state of solution of all partial projects took place and then Prof. Konvalinka informed about TA CR plans for the continuation of the NCC II program. The General Meeting agreed on the preparation of the project for the NCC II call, including the involvement of the Faculty of Civil Engineering of the Technical University of Ostrava, which expressed interest in cooperation. The preparation of the application for the extension of the existing NC for another two years was also approved.

- Under the auspices of the expert group “Drainage of Urbanized Areas CZWA” and the AdMaS Research Center, company ARDEC s.r.o. organized on October 3 and 4, 2019, in Velke Bílovice, the *XIX. International conference and exhibition "URBAN WATER 2019"*. As in previous years, the AdMaS Center presented a large number of conference posts.

- On October 23 and 24, 2019, the *Road Conference* was held at the Exhibition Center in České Budějovice. The Director of the AdMaS Center, Dr. Zdenek Dufek, Prof. Jan Kudrna, Ing. Petra Okrinova and Ing. Tomas Efenberk represented the research activities of the AdMaS Center and FCE as a whole in the exhibition stand and made contacts for possible future cooperation. Professor Kudrna presented a post on the topic *"Innovation of Classification of Variable Parameters of Road Surface"* on which he worked together with Dr. Jan Podrouzek, Ing. Karel Spies and Ing. Kvetoslav Urbanec from Consultest.

- Staff of the EGAR Research Group, led by Assoc. Prof. Jaroslav Raclavsky, performed during the year 2019 hydraulic assessment of the Znojmo sewerage network for Vodarenska akciova spolecnost, a.s. In 2018, measurements of selected hydraulic parameters were carried out on the sewer network, followed by the creation of a hydraulic model of the sewer network. The model was calibrated and verified according to the measured values and technical measures were proposed to improve the operation of the sewer network.

- In the autumn of 2019, the traditional practical training of BSP students of the course K within the subject Roads I (BM001) took place in the Road Laboratory of the AdMaS Research Center. Students saw a practical demonstration of asphalt mixture production and were also acquainted with modern laboratory equipment and with the possibility of its use during bachelor and master theses. Some of the students also had the opportunity to discuss common themes with Prof. Jan Kudrna, who is, among others, a pioneer using asphalt modified with crushed rubber from old tires (so–called rubber–asphalt).

- On December 2, 2019, employees of the Microstructure of Building materials Research Group of the AdMaS Center organized an excursion for students of the FCE M study program to an autoclaved aerated concrete production plant. Students thus had a unique opportunity to see all stages of production, from the preparation of raw materials, through the creation of building elements, to their expedition. A lecture with a presentation of the complete product offer of the producer was a part of the excursion, including variants of placing the elements in the construction.

- In December 2019, two foreign road researchers visited the AdMaS Center. Dr. Min – Chih Liao of NTUST Taiwan University of Taipei (National Taiwan University of Science and Technology) is involved in research in the field of asphalt surfaces and the use of recycled materials in roads. The other guest – Dr. Daumantas Zidanavicius from Lithuania – during his visit also lectured at the Institute of Roads. During the excursion at the AdMaS Center were both researchers acquainted with the equipment of the Road Laboratory. Mr Liao made a preliminary arrangement for future cooperation, particularly concerning studying exchanges.

- At the end of 2019, the EGAR Research Group obtained a support from the EEA financial mechanisms, resp. from the Iceland Liechtenstein Norway grants. At the turn of 2019 and 2020, the RG dealt with the Norwegian partners of the Norwegian University of Science and Technology in Trondheim, respectively with the Norwegian Institute for Water Research in Oslo, on current topics in urban engineering and wastewater treatment. The aim of the project with the Norwegian University of Science

and Technology is to prepare a joint doctoral study program in the field of water management and water structures, the effect of which is to strengthen institutional cooperation in the field of education. Young AdMaS researchers visited previously the University of Trondheim in the second half of October. An important part of the visit was a tour of the research infrastructure and a presentation of the functioning and setting of the parameters of the Norwegian doctoral program. The aim of the project with Norwegian Institute for Water Research is to strengthen research cooperation between BUT, resp. AdMaS and this research institution in the field of preparation of joint research projects for removal of antibiotics and antibiotic resistant bacteria in waste water.

- A team of authors from FCE, led by the director of the AdMaS Center, Dr. Zdenek Dufek, published at the end of the year *publication "Use of LNG in transport and energy and its safety"*. The aim of the publication is to introduce this type of fuel to the professional public, to acquaint with its basic physical properties, conditions of transport and storage and with the possibilities of its commercial use. Attention is also paid to the EU conceptual documents and outline the bases for safety standards. The publication is intended for a wide range of potential users who may encounter LNG in the coming years, as well as for petrol station designers, fire and road safety experts. At the same time, it is intended for employees of building offices who will permit the construction of refueling stations and tanks.

Further details of the sub–activities are given below for individual RPs.

4. Mobility of researchers and the cooperation with foreign countries

In 2019, the AdMaS Center intensified the mobility of its staff abroad under the Human Resources Policy. The aim was to further increase the number of workers from foreign universities to the AdMaS Center. This contributed to the creation of new partnerships and new areas of international cooperation (for example, with Brunel University of London, Oak Ridge National Laboratory USA, etc).

Details and examples of mobility for each RP are specified below.

5. Mobility of researchers toward the Application Sphere

The researchers' mobility towards the application sphere continued throughout the year. In most cases, these were one–day trips to carry out partial experiments, measurements, training, consultations, etc.

Further data and examples of mobility for each RP are specified below.

6. Achievement of Monitoring Indicators and Leading Indicators for 2019

In 2019, most of the planned values of the monitoring indicators were fulfilled and in some cases the annual planned values were significantly overfulfilled.

The fulfillment of the monitoring indicators was as follows:

Tab. 1: Personal MI

Indicator Code	Indicator	2019	
		plan	reality
110815	Number of students of all levels who use the built infrastructure / involved in the activities of the Center	92	**97**
110300	Number of newly created jobs, R&D employees – total	95,9	**124,22**
110302	Number of newly created jobs, R&D employees – women	28,77	**34,39**
071700	Number of newly created jobs, total researchers	71,8	**98,30**
071800	Number of newly created jobs, researchers – women	21,54	**23,25**
071900	Number of newly created jobs, researchers under 35 years	34,30	**55,60**
072000	Newly created jobs, researchers under 35 – women	10,29	**10,50**
074901	Number of successful graduates of Master's degree programs	64	**188**
074902	Number of successful graduates of doctoral study programs	18	**13**

Tab. 2: R&D outputs

Indicator Code	Indicator	2019	
		plan	reality
110502	Publications (Impacted Journals) (Jimp)	5	**26**
	Publications (others)	43	**66**
	Professional publications total	48	**92**
110503	National Patents	1	**0**
	Patents (International, Triadic (EU, US, Japan))	0	**0**
	Results of research protected on the basis of a special legal regulation 1	1	**0**
110504	Pilot plant, proven technology, variety… (Z, T)	10	**0**
	Prototype, methodology, utility and avg. pattern, ... (S)	27	**12**
	Applied Research Results 1	37	**12**

Tab. 3: Financial MI

Indicator Code	Indicator	2019	
		plan	reality
111200	Contract research volume	22000	**24040**
111300	Volume of R&D funds obtained from foreign sources	11500	**2267**
110720	Number of projects of cooperation of application sphere with regional R&D Centers	19	**21**
110603	The volume of funds received in a public tender for targeted support of national R&D resources	47035	**99539**

7. Research activities of the Center

7.1. Research programme RP1: Development of advanced building materials

7.1.1. Activities of Research Groups in the area of management

Head of RP – prof. Ing. Rostislav Drochytka, CSc., MBA, dr.h.c.
Deputy Head of RP – Ing. Zdenek Snirch, Ph.D.

Research group Microstructure of Building Materials

Head of RG – doc. Ing. Jiri Bydzovsky, CSc.
Deputy Head of RG – Ing. Vit Cerny, Ph.D.

Research group Technology of Building Materials

Head of RG – doc. Ing. Jiri Zach, Ph.D.
Deputy Head of RG – Ing. Adam Hubacek, Ph.D.

The achievement of the aims of Research Programme RP1: Development of Advanced Building Materials took place completely in accordance with the specialized focus and expected goals described in the technical annex for the year 2019.

7.1.2. Trainings and seminars

- On January 1, 2019, a training of employees from TRANSBETON a.s. was held. The topic of the training was *"The testing of fresh and hardened concrete".* All issues related to the design, preparation and testing of fresh and hardened concretes were discussed during the training. Another significant theme 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. The training also included a visit to the Center's laboratories, where the visitors were given a practical demonstration of testing and of the properties of fresh and hardened concretes.

- On January 9 and 10, 2019, a two–day seminar was organized for CEZ. It was a basic preparatory course for CEZ a.s. personnel, which included laboratory training. The course timetable comprised 14 hours of tuition, most of which took place in laboratories. During the course, issues concerning the design, preparation and inspection of the quality of fresh as well as hardened concretes were presented. Destructive and non–destructive concrete tests were also 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 familiarized

participants 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.

- On January 30, 2019, Assoc. Prof. Ing. Jiri Bydzovsky, CSc., gave a lecture at the seminar *"Execution and Inspection of Remediation Works on Concrete Structures"* organized by Betonconsult s.r.o., in the section Degradation Processes in Reinforced Concrete.

- On April 4, 2019, concrete technology training was provided for technologists employed at TRANSBETON a.s. 12 participants took part in the 1–day training session concerning the basics of concrete technology for transported concretes, including practical demonstrations of concrete testing.

- On April 15, 2019, a training of employees from BEST a.s. was organized. The training concerned concrete products produced using vibropressing technology, such as concrete paving blocks, slabs, kerbstones, masonry elements, blocks of lost formwork, palisades, sewer construction elements, etc. The main topic was the production, evaluation of properties and assessment of the conformity of these concrete products. The training also included practical demonstrations of the testing of concrete products in laboratories.

- On April 24, 2019, the specialized round of the *Student Scientific Activities (SVOC)* competition took place. Bachelor´s and Master´s degree students presented research activities which they mainly carried out at the AdMaS Research Center. The panels of experts consisted mainly of researchers from the Center.

- On May 14, 2019, a specialized training session on the topic of waterproof and watertight structures was held. The training called *"Waterproof and watertight structures"* concerned waterproof and watertight structures design, current guidelines and aids, and solutions involving the use of crystallization additives, coating insulations, grouting, and other repairs.

- On May 23 and 24, 2019, the AdMaS Center staff organized an international conference *"Ashes in the Building Industry"*. The conference focused mainly on the situation in the area of the production and evaluation of energy by–products in terms of current legislation and the primary orientation towards the evaluation of the final product. The topic of the conference was *"Fly ash and energy by–products as a synonym for secondary raw materials"*.

- On August 14, 2019, a training of employees from Semmelrock Stein+Design Dlažby s.r.o. was held. The topic of the training was *"The testing of vibropressed concrete products"*. The training involved the design, production and testing of concrete products produced using vibropressing technology, such as concrete paving blocks, slabs, kerbstones, masonry elements, blocks of lost formwork, palisades, etc. The training also included practical demonstrations of the testing of concrete products in laboratories.

7.1.3. Research staff mobility and cooperation with institutions abroad

In the case of Research Programme RP1, staff mobility to foreign partner universities took place for the purposes of teaching or study, and also as part of cooperation with foreign companies.

- In the period from July 15 till 18, 2019, Assoc. Prof. Lenka Bodnarova and Prof. Rudolf Hela took part in a research visit and training at Chryso, a company situated in Turkey.

- As part of Erasmus teaching + training, student Matjaz Sraml from the University of Maribor in Slovenia was present at the AdMaS Center from June 17, 2019 till June 19, 2019. He was acquainted with the Center's equipment and negotiated possibilities for mutual cooperation.

- In the period from July 1. till 5., 2019, Dr. Lenka Nevrivova, Dr. Martin Sedlmajer and Assoc. Prof. Nikol Zizkova followed up on the visit by their Slovenian colleagues from the University of Maribor to the AdMaS Center and took part in training at the University of Maribor in Slovenia. They got acquainted with the equipment available there, and options for mutual cooperation were discussed.

7.1.4. Research staff mobility: collaboration with industry partners

Close cooperation took place with many companies active in the construction industry in 2019. The Center collaborated both with manufacturers and companies that are users of building materials. Visits by RP1 researchers to such industrial entities took place throughout the year. In the majority of cases these were one– to three–day trips for the purpose of carrying out experiments or measurements, training, consultation, etc. In 2019 cooperation took place with Mapei Italy on the development of aeration additives for concrete, and with MC Bauchemie regarding the possibility of using building recyclates for the production of concrete during Prof. Hela´s doctoral student Ing. Labaj's multi–year work placement at MC Bauchemie Botrop.

7.1.5. Research activities of the RG 1

Implementation of VP1 targets by TA:

Fulfilment of the aims of Research Programme RP1: Development of Advanced Building Materials took place completely in accordance with the specialized focus and expected goals described in the TA for 2019.

- Researchers focused on research issues concerning, e.g. the development of new adhesives containing secondary raw materials for the application of non–absorbent lining elements in aggressive environments, the electrical and mechanical properties of fly ash geopolymer with carbon soot, and phase transformations induced by heat treatment in monolithic zirconium and yttrium aerogels. They also investigated the

recycling of soil in the form of self–compacting grouts, the use of alternative siliceous components in the production of autoclaved porous concrete, and the development of high–performance porous concrete. In addition, they studied the thermal and chemical resistance of a patching composite and the monitoring of microstructure depending on various types of binder and filler.

- In the area of mortars and plasters, researchers investigated, e.g. the relationship between the microstructure of carbonate rocks, calcite crystallinity and decarbonisation during lime firing, the effect of burning regime and potassium ions on the synthetic preparation of belite clinker and, for example, the relationship between the generation of hydration heat and the shrinkage of cement putty for various types of cement. Another area of interest was that of issues concerned with the study of the crystallization process during the preparation of tetracalcium ferroaluminate, the increase in the resistance of cement composites to sulphates, and the study of the structure of high–strength polymer cement composite modified by secondary raw materials. Also, the influence of cooling method on the formation of dicalcium silicate was investigated along with issues related to the effect of grinding on the granulometric properties of dicalcium silicate.

- As far as concrete technology is concerned, which is one of the key areas of activity particularly for the TBM group, investigative tasks were performed concerning the resistance of the surface of cement composites to mechanical wear due to abrasion, selected design adaptations of architectural concretes and their influence on mechanical parameters and durability, and also high–performance cement composites for architectural elements in which the formation of microcracks is eliminated. Other important areas of interest were the optimization of the design of a chemically resistant sprayed concrete, the development of a chemically resistant sprayed mixture and, last but not least, the development of the HVFAC static modulus of elasticity.

- Also, work was done regarding the development of ultra high–strength concretes – UHSC and reactive powder composites. In the experimental part, UHPC and RPC mixtures were designed and their compressive strength tested.

Tab. 4 : Compressive strength of UHPC

Recipe	UHPC 1	UHPC2
Compressive strength after 7 days [MPa]	117.3	114.2
Compressive strength after 90 days [MPa]	149.1	147.7

Tab. 5: Compressive strength of RPC

Recipe	RPC 1	RPC 2
Compressive strength after 7 days [MPa]	113.3	104.4
Compressive strength after 28 days [MPa]	136.9	132.2
Compressive strength after 60 days [MPa]	151.9	147.6

- Issues concerned with testing the options for anchoring UHSC in the steel envelope were also investigated. Research work was carried out using the Center's X–ray CT scanner (see Fig. No. 1).

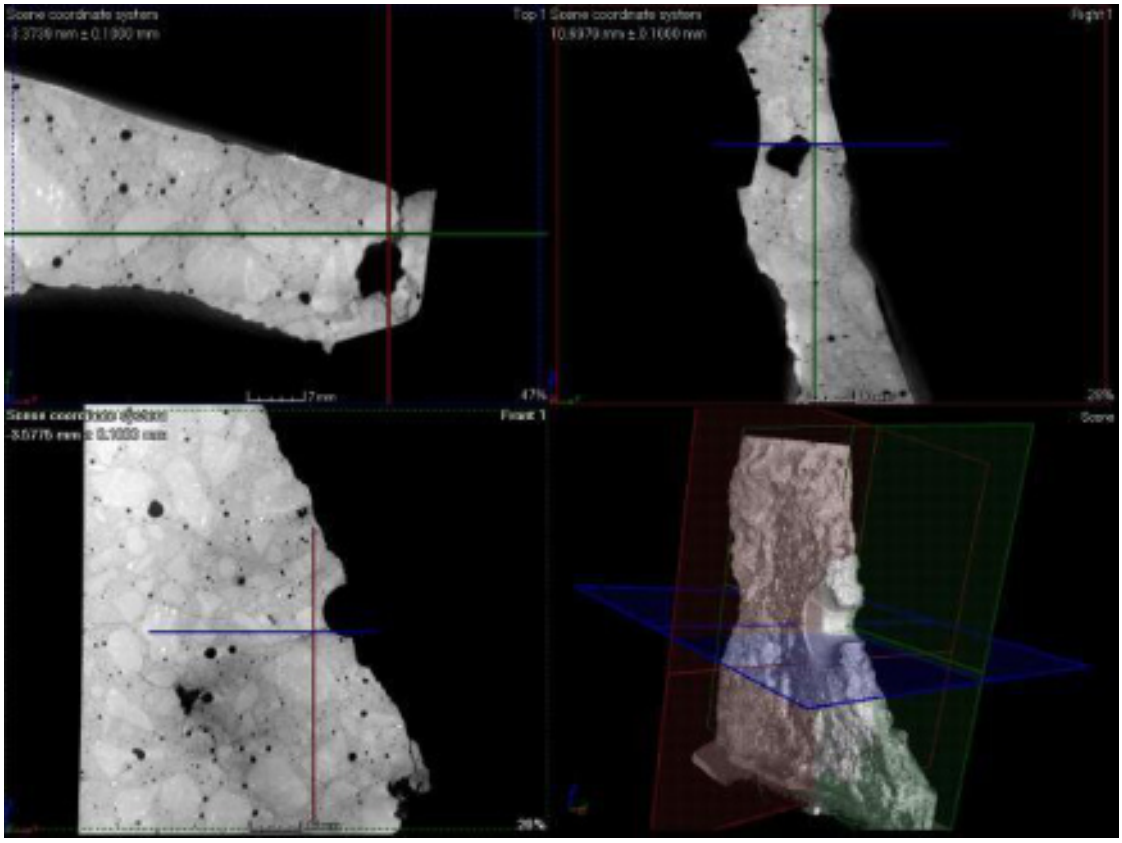

Fig. 1: CT photograph of concrete structure after the extraction of an anchor

- Cooperation with the company KrampeHarex GmbH & Co. KG, Hamm, Germany, is also under way in the area of testing the influence of fine fibres on the resistance of concrete to the effect of high temperatures. The effect of such temperatures on the behaviour of concrete was monitored, and tests were performed to investigate the addition of fine organic and inorganic fibres to the cement matrix. Specifically,

polypropylene, basalt, glass and PVA fibres were tested. Also studied was the effect of adding fibre in various doses on the workability of cement composites and on the properties of hardened cement composites (grain bulk density, compressive strength, flexural and tensile strength, and durability, particularly with regard to the resistance of cement composites with fibre reinforcement to the abrasive effect of solid particles and flowing fluids).

- As far as environmentally focused topics are concerned, researchers focused on, e.g. the use of hazardous waste in the development of a mechanically resistant composite material which utilizes pre–treated hazardous waste, the possibility of using specially adapted hazardous waste as a filler in polymer grouting materials, and also as a filler in polymer mortars, the use of fibreglass recycled materials in materials employed for the remediation of concrete structures, and the verification of the basic properties of recycled and natural aggregates.

- From the other interesting topics which were investigated during the scientific research activities of Programme 1 we could name, for instance, trenchless methods of sewer network renovation, including the solution of the variation in the thickness of the hardened sleeve; the synthesis of forsterite ceramics using fly ash as a raw material, and its effect on the resultant properties of the fired ceramic body; the monitoring of the influence of crystallization additives on the porosity of cement mortar reinforced with polypropylene fibres; the influence of the length of the maturing period for raw materials on the final properties of high–alumina grog in the area of ceramics; and the influence of micro particles of Al2O3 on the pore structure of baked clay.

- Year 2019 saw the implementation of several specific research projects in which Ph.D. and Master´s students were heavily involved. As regards areas concerning the use of secondary raw materials, these include a study of the use of such materials in light mortars, which is being investigated in cooperation with the Faculty of Chemistry at BUT. In the area of coatings there is a project which focuses on the synthesis, processing and characterization of the advanced BaO–MgO–Al2O3–SiO2 system as a coating for the future; this investigation is taking place in cooperation with CEITEC. Other research projects are concerned with the following: special polymer coating materials utilizing hazardous waste and secondary raw materials, the synthesis of pure phases of Portland clinker, the effect of accessory oxides in feedstock on the properties and synthesis of forsterite ceramics, the optimisation of the usability of active and passive admixtures in the production of high–performance concrete mixtures with a low degree of water separation, the examination of the options for using suitable secondary raw materials in the optimization of a silicate sprayed mixture, the options for making maximum use of secondary raw materials and porous concrete grit in porous concrete production techniques, the evaluation of the usability of the non–destructive ultrasound method for the prediction of alkaline–siliceous reactions, the study of tobermorite in order to create a comparative database to understand changes in the microstructure of lime silicate composites, the design of concretes for “white tanks” with optimized dosages of fine components and with regard to the reduction of volume changes.

- The staff in the physical part of the programme investigated the following topics: the relationship between the resonance frequency and ultrasonic velocity of thermally

exposed concrete, the comparison of acoustic absorbers applied on fixed track, the analysis of dynamic effects in one part of railway switches, the evaluation of the structural changes in fine–grained cement composites using acoustic tests, the possibility of using non–linear acoustic spectroscopy with a single excitation signal to test concrete elements damaged by high temperatures, the monitoring of the development of thermal damage in concrete elements using acoustic NDT methods, the electric properties of geopolymer composites with fly ash with graphite conductive admixtures, the improvement of the electric properties of composites with fly ash using carbon nanotubes, and the measuring of acoustic emission on fibre concrete slabs.

- RP1 staff constantly and actively publish the programme's achieved results at significant scientific conferences and in important international journals, thus presenting not only the latest findings from the area of research and development but also the AdMaS Center itself. Through these activities, new contacts are made for future cooperation in the area of R&D and the acquisition of sub–contracts. Achieved results are also registered in the form of functional samples and verified technologies, etc., and may be legally protected via utility models and patents. It is not only important that research workers in senior researcher positions are significantly involved in the activities of the research groups, but also (and indeed mainly) that young people in junior researcher positions additionally cooperate closely with Bachelor´s, Master´s and Ph.D. students and pass on their experience to them.

Examples of significant R & D outputs:

- A functional sample named *"A green facade suitable for interior spaces"* was registered as part of the project *"Development of green facades and the study of their impact on the environment and on the health of the population".*

- In the thematic *area "Comprehensive system of special patching materials using secondary raw materials for industrial operations"*, two utility samples were registered under the names "A high–resistant patching composite for the reconstruction of buildings made of fused basalt using secondary raw materials" and *"An admixture for cement–based grouting material".*

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

- GA17–00243S – A study of the behaviour of insulation materials under extremely lowered pressure,
- GA17–14198S – Kinetics of silicate microstructure formation in relation to hydrothermal conditions and type of input raw materials,
- GA17–24954S – Conditions for the thermodynamic stability and transformation of AFt phases,
- GA18–02815S – Elimination of sulphur dioxide emissions during the firing of ceramic body manufactured using power plant fly ash,

- GA18–25035S – A study of the effects of flowing fluids on the erosive wear of cement composites, and the subsequent modelling of mechanical corrosion,
- GA19–00291S – Analysis of processes in the formation of the structure of silicate composites with organic fillers, and their behaviour under specific stress conditions,
- GA18–25035S – A study of the effects of flowing fluids on the erosive wear of cement composites, and the subsequent modelling of mechanical corrosion.

- Furthermore, a National Competence Center sub–project was successfully acquired: TN01000056 – Center of Advanced Materials and Efficient Buildings (CAMEB). The project recipient is CTU in Prague; other participants include 3 universities (incl. BUT) and 26 other subjects. The investigator representing BUT is Prof. Rostislav Drochytka. Within the framework of the Center, Research Programme RP1 submitted and received sub–project N01000056/04 – Advanced materials and technologies (ADMATEC). The project focuses on research and development concerning new advanced materials for the building industry, their testing, monitoring of their long–term properties and durability, as well as subsequent recycling after the end of their lifespan. Thanks to this, it contributes to the expansion and optimization of the raw materials base, particularly through the employment of renewable and secondary raw materials.

Information on the use of purchased equipment:

Within the project, effective use was made of key laboratory equipment such as a X–ray CT scanner, XRD system with Rietveld refinement, high–temperature chambers and SAXS, SEM with an environmental probe and 3D imaging, Q–SUN and QUV chambers, and corrosion chambers capable of simulating the action of aggressive gases or salt fog.

SEM was used for:
- the analysis of the microstructure of hydrothermal CSH phases of hydrothermal materials (MPO FV10284),
- the study of phase transformation during the dehydration of gypsum in acid solutions,
- the study of anhydrite binders,
- the analysis of the composition of cement bypass dust,
- the study of the effect of the synthesis of pure silicate phases on their properties,
- the analysis of the thermodynamic stability and structure of ettringite and thaumasite (GA17–24954S),
- the study of the formation and hydration of ternesite (GA17–24954S),
- the monitoring of the development of historical binders for historical mortar and plaster,
- the monitoring of the ratio of tridymite x cristobalite during the firing of refractory materials,
- the study of the effect of crystallization admixtures on the structure of cement composite (GA16–25472S),
- the monitoring of corrosion products formed in the body of the Hlavka Bridge,
- the analysis and study of fluid bed combustion and high–temperature fly ashes,
- the study and verification of the kinetics of hydration of the binder used for the base layers of the Cheb – Karlovy Vary motorway,
- investigations carried out during the preparation of Bachelor´s and Master's theses concerning the area of high–performance cement composites, the use of secondary

raw materials in building materials, the development of polymer materials, porous concrete products, etc.

XRD was used not only for the above–mentioned Czech Science Foundation projects but also for research in areas such as:

- the thermodynamic stability of AFT phases based on ettringite and thaumasite (GA17–24954S),
- research into the reactivity of lime, and the study of the crystallization of hydrate (dissertation – Ing. Dolak, Ing. Sklenarova),
- the influence of the genesis and type of limestone on the properties of lime and hydrates, and the production process (dissertation – Ing. Dolak),
- the study of honey crystallization,
- the synthesis of pure silicate phases and their properties, and the study of the formation of alite polymorphs (dissertation – Ing. Ravaszova),
- the study of the thermo–technical properties of BMAS (Interfaculty Special Research FCE – CEITEC),
- the study of phase transformation during the dehydration of gypsum in acid solutions (diploma thesis – Ing. Zajeda),
- hydration processes in ternesite clinkers (GA 17–24954S),
- the study of refractories, mullite and crystobalite (TH02020321),
- the study and analysis of historical binders for historical mortar and plaster,
- anhydrite binders and hydration products,
- the study of the effect of raw materials on the content of tobermorite (MPO FV10284),
- the monitoring of firing with regard to the ratio of tridymite x cristobalite in refractory materials; analysis of the level of crystallization of crystallization admixture added to concrete (GA16–25472S),
- mineralogy and the effects of the composition of clay minerals (dissertation – Nguyen),
- the mineralogical analysis of fluid bed combustion and high–temperature fly ashes (dissertation – Ing. Tazky),
- phase changes during the hardening of concrete (dissertation – Ing. Tazky),
- measurements conducted during Bachelor's and Master's thesis research concerning the use of fly ashes and epoxides, the preparation of agloporites, etc.,
- the study and characterization of corrosion products which appeared in the body of the Hlavka Bridge,
- the analysis of the stability of concrete from cooling tanks at the Dukovany nuclear power plant,
- the analysis of by–products from the production of cement–bonded particleboards and other potentially suitable alternative substitutes for composite binder with cement matrix and organic filler (diploma thesis – Ing. Dobrovolna, Ing. Urbanek, MPO TRIO, FV30072).

X–ray CT scanner was used for sample analysis in connection with:

- the distribution and homogeneity of scattered reinforcement,
- the investigation of layers of a silicate–based floor system,
- the fracture failure of cement–bonded particleboards,
- the characteristics of glued joints in wooden composites,
- the mechanism and depth of the abrasion of samples treated using a water jet,
- the penetration of anchoring materials into a concrete base,
- the characteristics of the surface of concrete reinforcement,
- the direct connection of original and new concrete without the use of bonding agent,
- the analysis of pipeline welds for the Dukovany nuclear power plant,

- continuing collaborative research with TUO (the Technical University of Ostrava) into the effects of wolfram sub–calibre ammunition during the penetration of steel armour plating,
- collaborative research with TUO into the effects of the mechanical processing of cold alloys,
- collaborative research with CEITEC regarding components such as rangefinders, turbine blades, filters and car restraint systems, connectors, electric coils, etc.,
- silicate matrix–based composites modified by various alternative raw materials in combination with an organic filler – particularly the distribution of the filler in the matrix and possible defects or anomalies in the structure,
- boreholes in high–strength concrete from real structures, with an evaluation of the structure before and after dynamic cyclic loading, in cooperation with Austrian and German universities.

WUV and QSUN devices were used in the following way:

- as part of the investigation of project CZ.01.1.02/0.0/0.0/17_205/0014381, the QUV tester was used to simulate the accelerated degradation of newly developed alkali–activated matrix–based composite materials and the surface finishes of garage door segments manufactured by KRUZÍK, s.r.o. Following on from work done in 2018, the testing and evaluation of adverse effects on materials continued according to newly formulated and unique methods of achieving accelerated degradation. These include the use of the QUV tester when it is necessary to verify the real durability of surface finishes applied by digital printing over a period of about 10–12 years during laboratory exposure lasting approximately 1 year only. The QUV chamber enabled the simulation and monitoring of the influence of a combination of increased temperatures, UV radiation (specifically the UVA–340 type, i.e. with a wavelength of 340 nm, at a temperature of 60 °C) and condensed moisture (at a temperature of 50 °C) on changes in the properties of surface finishes applied directly to galvanized steel sheeting (which sees real–world application in the production of jointed garage door segments). The conditions listed above were alternated cyclically. A significant part of the investigation was the modification of surface finishes by varnishes with different material bases so that the longest possible lifespan could be guaranteed for the final surface finishes,
- before the start and also during the course of adverse exposure (particularly in the Q–SUN chamber), differences in colour parameters (CIELAB colour space) were monitored and evaluated using a CMD–600D spectrophotometer, during which the parameter ΔECMC was used for the monitoring of changes,
- photoluminescent pictograms applied to several types of various bases (glass, plastic and metal) representing real applications were irradiated in the Q–SUN device as part of contract research for the company SYNPO a.s. The pictogram samples were tested according to defined exposure conditions (according to the IVECO 16–0180 standard, table 1, method B) using filters of the X–7460 Daylight–Q type. The irradiation took place in combination with the spraying of the test specimens for a period of 1500 hours; the radiation intensity was 0.35 W/m2 and the insulated black body temperature was 65 °C (chamber temperature 40 °C).

HK 800/M/WTG corrosion chambers, which enable the simulation of environments containing aggressive gases, were used mainly for the following activities:

- the dynamics of the degradation of cement composites modified via secondary crystallization were investigated. Specifically, emphasis was placed on the achievement of the required environment in accordance with the provisions of the ČSN EN ISO 3231 technical standard, where the procedure for the verification of resistance during exposure to humid atmospheres containing sulphur dioxide is described. This is a relatively aggressive gas whose effect is potentiated by higher temperatures and

humidity, resulting in very unfavourable conditions that significantly accelerate the degradation of tested specimens,

- the procedure described above was also used to test newly developed surface finishes applied to garage door segments (CZ.01.1.02/0.0/0.0/17_205/0014381, made by the company KRUZÍK, s.r.o) via digital at the greatest concentration stated in the quoted standard, i.e. 2.7l of gas for a space with a volume of approx. 0.8 m^3. The evaluation of the boards' exposure to this treatment occurred both continuously during the test (via the observation of hue changes using a spectrophotometer and the taking of photographs in the "macro" mode) and after the end of the required number of cycles (via the testing of adhesion to the base, thickness, resistance against the separation of the surface finish from the base, etc.),
- the chambers were also used for the testing of anchoring elements for use with concrete and TR metal sheeting according to ETAG 006 using the Kesternich test. The test equipment and procedure were defined in accordance with the CSN EN ISO 6988 working procedure,
- this year (as in the previous year 2018), one of the HK 800/M/WTG corrosion chambers was also used for the simulation of salt fog in accordance with CSN EN ISO 11997–1, 2. Digitally printed surface finishes were loaded with this adverse environment (CZ.01.1.02/0.0/0.0/17_205/0014381, KRUZÍK, s.r.o.). Cyclic loading with a sprayed solution (salt fog) containing an increased concentration of NaCl and (NH4)2SO4 ions took place at an increased temperature (35 °C) and with an accumulation speed of 2 ml/h. The following phase involved an environment with a relative humidity of 100% and a temperature of 40 °C, this being followed by a drying stage with a relative humidity of 50% and a temperature of 23°C. The samples subjected to this exposure were evaluated both continuously (via the observation of hue changes using a spectrophotometer and the taking of photographs in the "macro" mode), and after the end of the required number of cycles (testing of adhesion to the base, thickness, resistance against the separation of the surface finish from the base, etc.).

Laboratory incubator with a CO2 atmosphere was mainly used for the following activities:

- the exposure of test specimens, such as cement matrix and organic filler–based composites, as well as alkali–activated concretes (project GA19–04703S: The use of non–destructive methods to test the condition of degraded alkali–activated concretes) and silicate composite materials in an environment with defined conditions. These characteristically feature an increased concentration of carbon dioxide, which reacts with cement matrix products and thereby causes a chemical reaction (carbonation). This year, the incubator mainly saw use storing cement bonded particleboards of modified composition on a long–term basis. The effect of carbonation upon the boards will subsequently be monitored, both in terms of the depth of carbonation and basic physico–mechanical parameters, including phase composition and microstructure.

RP1's mobile laboratory was used for trips to perform measurements and take samples. These were mainly visits to production plants, to concrete structures under evaluation, to aggregate storage sites, and to specific construction sites. In general, it was the following type of work:

- the taking of samples from boreholes with diameters of 75, 100 and 150 mm drilled into vibropressed and cast products for street drain inlets, sumps, water shafts, shaft bases, gullies, manhole covers, cones, and grade rings with inner diameters of 250, 500 and 1000 mm, etc. Samples with the above–mentioned diameters were also taken from structures to determine the physico–mechanical parameters of the structure and structural elements. Laboratory tests were performed on the modified borehole cores

to determine the following: compressive strength, resistance to type C chemical de–icing agents, volumetric weight, the depth of penetration of water under pressure, and static modulus of elasticity. Subsidiary tests were then performed on the whole products to determine the following: the thickness of the cover layer of the reinforcement, absorptivity, the vertical and horizontal load–bearing capacity of steps, peak load–bearing capacity, capillary absorptivity, and frost resistance. The results of the analyses subsequently lead to the creation of background materials for experimental activities and the optimization of recipes, etc.,

- the taking of samples and measurement of the basic characteristics of aggregate (mined, crushed, waste), for which grain size was determined using sieve analysis, as well as grain bulk density, absorptivity after 24 hours, shape index determination, sand equivalent value determination, bulk weight, void content, resistance against freezing and defrosting, compressive strength, bulk weight of loosely poured and shaken aggregate, the quantity of washoff particles and the evaluation of fine particles in limestone samples (methylene blue test). The determination of lightweight polluting substances, granulometry and the potential presence of humus was also performed. In the case of fine–grained samples, the granulometry curve was determined using laser diffraction analysis (detection of particles of sizes ranging from 0.02 to 2000 μm),
- the in–situ testing of fresh concrete to determine, for example: air content, consistency (by slump test), and the density and shrinkage of fresh concrete. Laboratory samples were prepared and subjected to physico–mechanical tests in order to ascertain the following: compressive strength, tensile and flexural strength, the depth of penetration of water under pressure, resistance to chemical de–icing agents, absorptivity, and the characteristics of air pores,
- the production of test specimens (cylinders, prisms, cubes): the specimens were subsequently subjected to frost resistance tests and the density of the hardened concrete was determined, as well as the tensile and flexural strength, compressive strength, direct tensile strength, resistance to chemical de–icing agents, depth of penetration of water under pressure, absorptivity, humidity, static modulus of elasticity, watertightness, spacing factor, and shrinkage. The modulus of elasticity and deformation were determined for fibre concrete,
- the taking of samples for the testing of small concrete products such as: flat tiles, interlocking pavement, road and pavement kerbstones, slope blocks, ceiling inserts, lost formwork, coping stones, grassing blocks, concrete gutters, transition slabs, masonry elements, drainage and cable gutters. Subsequently, flexural, transverse tensile and compressive strength were determined for them, along with abrasion resistance (Böhme), resistance against chemical de–icing agents (type A and C), and absorptivity. The slip resistance properties of the surface were measured via the pendulum test, and adhesion tests, tear tests, and qualitative tests of dimensional tolerance and flatness were performed. Slip resistance was determined for slabs made from natural stone, and also densities, the strength of sidewalls in flexure, capillary absorptivity, and frost resistance,
- the taking of samples of aggregate manufactured by the company Tech Trading under the brand name Liapor, and the determination of their basic parameters, followed by further testing of their suitability for use in light concretes, focusing on factors such as absorptivity, bulk density and compressive strength,

- the execution of preliminary, main and complementary engineering surveys in the field: tearing tests, analysis of the durability of structures, crack widths, evaluation of surface hardness using a Schmidt hardness tester, the detection and analysis of reinforcement corrosion, the design of remedial measures, the testing of the adhesion to base of surface finishes of building structures,
- the inspection testing of fresh concrete during the concreting of motorways to determine consistency (via slump test), air content, and the density of fresh concrete. The taking of samples for the further laboratory testing of physico–mechanical properties such as compressive, tensile and flexural strength, the depth of penetration of water under pressure, resistance against chemical de–icing agents, and frost resistance,
- the execution of research into the durability of anhydrite floors, the testing of proportional strain, the investigation of the anti–slip resistance of surfaces, the measurement of humidity.

Major R & D projects with application sphere and other activities:

Cooperation with partners in projects from the Ministry of Industry and Trade, the Technology Agency of the Czech Republic and the Czech Science Foundation took place at an excellent level, as it did with our contractual research partners. The activities of the individual cooperating organizations complemented one another efficiently. It was necessary to collaborate with producers of raw materials, manufacturers of materials and parts, organizations planning to apply for research funding in the future, and other research organizations.

The following specific cases can be named as examples:

- Cooperation with KOMFORT, a.s. on project FV10118 – Progressive waste–free technology for the re–usability of soil in the form of self–compacting grouts. In terms of cooperation, the development activities of BUT are synergically connected with KOMFORT's great experience in the field of construction.

- Cooperation with PORFIX CZ a.s. on the following projects:

  i, FV10284 – Advanced technology for the production of sand–based porous concrete with added secondary raw materials and more efficient utilisation of natural resources,

  ii, FV30327 – Advanced waste–free technology for the production of high–performance porous concrete with the use of renewable resources.

  PORFIX, CZ a.s. has had many years of high quality practical experience as a producer of porous concrete, allowing the company to provide ideal support for the development of materials using new sources of raw materials at FCE Brno.

- Cooperation with Prefa Brno a.s. in the investigation of project FV10680 – Development of prefabricated components made from HWC and HPC for special applications in precision engineering and radiation protection. Prefa Brno a.s. has been

a BUT partner for many years, both in the area of research and development and in the testing of its own products.

- Cooperation with Skanska Transbeton, s.r.o and Skanska a.s. on project FV20019 – Optimization of the granulometry of fine graded particles in concrete to obtain high–performance concretes.

- Cooperation with REFAGLASS s. r. o. on project FV20086 – Development of lightweight modern building materials utilizing light glass powder–based aggregate. This is an example of a project connecting the research findings of BUT with a real–world industrial entity.

- Cooperation with RETEX a.s. on project FV20127 – Research and development in the field of advanced thermal and acoustic insulation materials based on waste textiles and natural fibres.

- Cooperation with BETOSAN s.r.o. on project FV20149 – A comprehensive system for the remediation of chemically attacked and stressed structures.

- Cooperation with Redrock Construction s.r.o.

  i, FV20303 – Progressive polymer materials utilizing secondary raw materials and hazardous waste for use in chemically highly aggressive environments,
  ii, EG15_019/0004734 – Research and development in the field of mechanically and chemically resistant composites based on cement and non–cement binders and secondary raw materials,
  iii, TH02020415 – Advanced adhesive materials with high proportions of secondary raw materials for extremely stressed environments.

  Again, this represents an optimum connection between the high research potential of FCE and the production and development activities of a company which has broad experience in the application of its own product in real conditions.

- Cooperation with FEVA, s.r.o. on project FV20530 – Unique formwork system with a protective anti corrosion function.

- Cooperation with TOS KURIM – OS, a.s. on project FV 20595 – Steel–concrete structures for precise machine tools.

- Cooperation with CIDEM Hranice, a.s. on project FV30072 – Effective optimization of the use of waste from the production of cement–bonded particleboards in the production of competitive building materials.

- Cooperation with BETONCONSULT, s.r.o. on project FV30239 – Advanced materials enhancing earthing in a lightning and overvoltage protection system.

- Cooperation with CONSULTEST s.r.o. on project FV30325 – Application of laser and radar road measurements in the diagnostic analysis of the cement–concrete covers of

motorways, with the use of physical and chemical analyses performed on concretes to limit the concrete degradation processes that lower the lifespan of highway pavements.

In 2019, new cooperation began not only in the execution of basic and applied research, but also within the framework of contract research. The newly–started projects include:

- **MPO TRIO FV40081** – Advanced technologies for the establishment and restoration of the structural layers of railway substructure with the efficient use of secondary raw materials, investigated in cooperation with INFRAM a.s.

- **MPO TRIO FV40343** – Silicate–based structural systems of paved surfaces and roads for ecological rainwater management, investigated by Lias Vintirov, lehký stavební materiál k.s.

- **TACR EPSILON TH04020378** – Development of new technologies and products for sustainable construction in the area of masonry structures, investigated in cooperation with Wienerberger s.r.o.

- **TACR EPSILON TH04030425** – REIZO – Development of technology for a line for the recycling and material use of waste from insulating materials, investigated in cooperation with VIA ALTA a.s.

- **Czech Science Foundation GA19–00291S** – Analysis of processes occurring during the formation of the structure of silicate composites with organic fillers, and their behaviour under specific loading conditions

Photo documentation from performed scientific research works (see Fig. No. 2 – 16)

Fig. 2: Photo showing the condition of a concrete weir structure

Fig. 3: Determination of the depth of carbonation on the weir structure

Fig. 4: Extraction of a borehole core from the weir structure

Fig. 5: Experimental verification of soil liquefaction (spillage measurement using a MARSH cone)

Fig. 6: Experimental verification of soil liquefaction (“in situ” application)

Fig. 7: Experimental verification of soil liquefaction (collection of samples)

Fig. 8: Collection and basic determination of the properties of coal slag samples

Fig. 9: Determination of hue changes after exposure in the Q–SUN chamber using a spectrophotometer

Fig. 10: Samples of photoluminescent pictograms during exposure in the Q–Sun chamber

Fig. 11: Samples of photoluminescent pictograms during exposure in the Q–Sun chamber

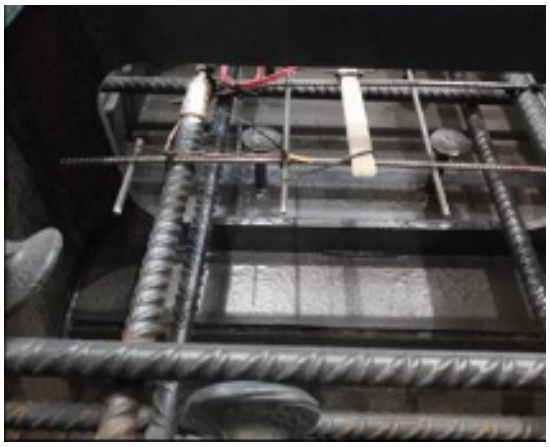

Fig. 12: Preparation of strain gauges for the determination of concrete shrinkage

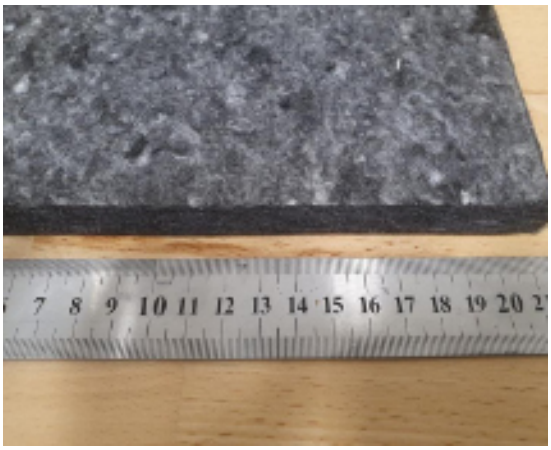

Fig. 13: Development of recycled textile insulation with RETEX a.s.

Fig. 14: Development of lightweight plasters using light foam glass–based aggregate (cooperation with Refaglass)

Fig. 15: Cement bonded particle boards in the test for determining the reaction to fire by the action of a single burning object. From left: test specimen installed on trolley, specimen during test, specimen after test

Fig. 16: Fire resistance testing of concrete segment using polymer fibers to increase fire resistance of concrete, at isothermal durability of 1000 ° C

7.2. Research programme RP2: Development of advanced structures and technologies

7.2.1. Activities of Research Groups in the area of management

Head of RP – prof. Ing. Jan Kudrna, CSc.
Deputy Head of RP – Ing. Pavel Šperka

Research Group STC (Structures and Traffic Constructions)

Head of RG – Assoc. Prof. Pavel Schmid, Ph.D.
Deputy Head of RG – Ing. David Beckovsky, Ph.D.
– Ing. Pavla Nekulova

The members of Research Group RP2–RG1 Structures and Traffic Constructions act as the guarantors for individual areas of R&D. The individual research areas, divisions and guarantors are as follows in 2019:

Construction division
Diagnostic Analysis of Structures and Building Testing (SZK) – Ing. Vera Hermankova, Ph.D.
Concrete and Masonry Structures (BZK) – Ing. Ivana Lanikova, Ph.D.;
Metal and Timber Structures (KDK) – Ing. Michal Strba, Ph.D.;
Mathematical Modelling (MAT) – Prof. RNDr. Josef Diblik, DrSc.

Transport Structures division
Roads, Highway Engineering (PKO) – Ing. Pavla Nekulova;
Railway Engineering (ZEL) – Assoc. Prof. Ing. Otto Plasek, Ph.D.;
Computer–aided Engineering and Computer Science (AIU) – Assoc. Prof. Mgr. Tomas Apeltauer, Ph.D.

Building Structures division
Building Construction (PST) – Ing. David Beckovsky, Ph.D.;
Technology, Mechanization and Construction Management (TST) – Ing. et Ing. Barbora Necasova, Ph.D.

Research Group EGAR

Head of RG – Prof. Ing. Petr Hlavinek, CSc. MBA
Deputy Head of the RG – Assoc. Prof. Ing. Jaroslav Raclavsky, Ph.D.
– Ing. Tomas Chorazy, Ph.D.

The EGAR research group works in the mode of guarantors of partial parts of applications, resp. field areas of R&D. The individual research areas – divisions and guarantors in 2019 are as follows:

Urban Engineering – Assoc. Prof. Ing. Jaroslav Raclavsky, Ph.D.
Geoinformatics – Ing. Zdenak Krejza, Ph.D.

Geotechnics – Assoc. Prof. Ing. Lumir Mica, Ph.D.
Energy Diagnostics of Buildings and Regions – Prof. Ing. Jiri Hirs, CSc.

It remains typical for RG EGAR that cross–sectional topics and complex themes are sought alongside those specific to the group's individual application areas.

As regards the promotion of the AdMaS Center and the EGAR group, presentations have been taking place for selected partners from the construction industry, the operators of water management systems, waste handling companies, etc.

RG EGAR participates significantly in the holding of public events. In 2019, these included:

- Active participation by Prof. Hirs, CSc. as a member of the Brno delegation at *Smart City Summit & Expo Taipei 2019* in Taiwan from March 25 till 29, 2019. The event included meetings with a representative of the Ministry of Economic Affairs and visits to three local universities and a national research Center (Research Technical Institute) – presentation of AdMaS, the Smart Regions project and the city of Brno.

- Active participation of Prof. Jiri Hirs in the committee for education and committee for research on May 24 and 25, 2019 as a delegate of the Czech Republic at the *General Assembly of REHVA* in Bucharest.

- Visit by Dr. C.T. Aravindakumar, professor at the School of Environmental Sciences of the Mahatma Gandhi University in Kottayam, India, concerning the deepening of mutual cooperation and the preparation of scientific topics and mobility.

The EGAR group uses shared data storage to keep documents related to its activities. Business strategy is created at the level of the individual sub–groups due to the diversity of their interests. The aim, however, is to look for crossover themes which reappear again and again, as in (for example) the case of the Smart City topic when creating intelligent city concepts. The creation of the business strategy is based on the current requirements of the market, which is constantly monitored. This takes place (for instance) via the presentation of papers and outputs from specialized conferences during the above–mentioned meetings. The business strategy is adapted according to this up–to–date information. Information about business strategy is submitted to the management of the EGAR RG.

Research Group MM (Mathematical Modelling)

Head of the RG – Prof. Ing. Drahomir Novak, DrSc.
Deputy Head of RG – Prof. Ing. Zbynek Kersner, CSc**.**

Guarantors of individual topics:

Soft–computing – Prof. Ing. Drahomir Novak, DrSc.
Reliability – Assoc. Prof. Ing. David Lehky, Ph.D.
Fracture mechanics – Prof. Ing. Zbynek Kersner, CSc.
Discrete approaches to modeling – Assoc. Prof. Ing. Jan Elias, Ph.D.

The group supports young workers, collaborates with other research groups and applies research results in practice. The research results also publishes in foreign impact journals.

7.2.2. Trainings and seminars

Research Group STC (Structures and Traffic Constructions)

The RG's important activities in the area of training and the organization of seminars mainly include the following:

- Workshop *"Description of the SZDC Network"*, January 9, 2019, Prague. The event focused on the information systems used with railway lines managed by the SZDC.

- A series of four workshops on the topic "Concrete in Context" with a focus on New Structures, Interesting Structures – March 7, 2019; Failures and Reconstructions of Buildings – March 3, 2019; Research and Development and its Practical Outputs – April 4, 2019; and the Monitoring of Structures and "Smart" Structures – April 25, 2019. The aim of the workshops was to get students acquainted with the activities and research carried out at the Institute of Concrete and Masonry Structures.

- Seminar *"Malvern Panalytical, Phenom and 3P Instruments"*, held from May 22 till 23, 2019 in Brno. It focused on basic and advanced methods of measuring data using a dynamic shear rheometer, a device which is designed to measure the rheological parameters of asphalt binders and other viscoelastic substances. Methods of evaluating the obtained data were also covered.

- Workshop *"Diagnostic System for Switches Based on the Measurement and Evaluation of Dynamic Effects"*, June 19, 2019, Prague. The event focused on the diagnostic analysis and monitoring of switches and switch structures.

- Workshop *"Research Activities of the Institute of Concrete and Masonry Structures Profit Center and Cooperation with Industry"*, June 26, 2019, Brno. The event focused on the presentation of the institute's cooperation with industry within the framework of research projects, along with the results achieved and potential areas for further cooperation.

- Organization of specialized section No. 56 *"Dynamical systems and their applications to advanced materials, structures and technologies" at the ICNAAM conference (International Conference on Numerical Analysis and Applied Mathematics)*", 15 contributions, Sheraton Hotel, Ixia, Rhodes, Greece, September 23 till 28, 2019. The proceedings are being prepared for publishing in the AIP (American Institute of Physics) Conference Proceedings 2020.

Research Group EGAR

- September 4, 2019, hosting an excursion to the AdMaS Center as part of cooperation with the project *Young Energy Europe*. The excursion to the AdMaS Center took place as a practical part of training in the Young Energy Europe project, which is financed via the European Climate Initiative (EUKI). EUKI is a financial tool of the German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU). EUKI's main aim is to foster cooperation within the European Union with the goal of supporting the lowering of greenhouse gas emissions and intensifying the dialogue and the exchange of knowledge and experience within Europe based on the Paris Agreement.

- November 26, 2019, Workshop: „*Final disposal of spent nuclear fuel in hard rock*“. The workshop by recognized specialist Prof. Ove Stephansson focused on practical experience with the planning and construction of a deep repository for radioactive waste in the granite and gneiss rocks of the Baltic Shield.

- November 27, 2019, Workshop: „*Rock stress and rock stress measurements for locating, designing and constructing a repository for high–level radwaste*“. The workshop by recognized specialist Prof. Ove Stephansson focused on the detection and measurement of rock stress in relation to the localization and construction of a deep repository for nuclear waste.

Research Group MM (Mathematical Modelling)

- From May 20 till 24, 2019 RG MM organized a lecture by Assoc. Prof. Hector Cifuentes from the University of Seville in Spain.

7.2.3. Research staff mobility and cooperation with institutions abroad

Research Group STC (Structures and Traffic Constructions)

Visits to institutions abroad:

- Mgr. Hana Halfarova, Ph.D.: educational visit via the ERASMUS+ programme, Poznan University of Technology, Poznan, Poland.

- Tomas Koudelka: Eurovia’s Central Laboratory, Bordeaux, France.

- Ing. Ondrej Anton, Ph.D.: Faculty of Civil Engineering, Technical University of Kosice, Slovakia.

- Ing. Vera Hermankova, Ph.D.; Faculty of Civil Engineering, Technical University of Kosice, Slovakia.

- Ing. Pavel Liska, Ph.D.: Tokyo Institute of Technology and the University of Tokyo, Tokyo, Japan.

- Ing. Pavel Liska, Ph.D.: Sungkyunkwan University, Suwon, Republic of Korea.

- Ing. Barbora Kovarova, Ph.D.: Slovak University of Technology in Bratislava, Bratislava, Slovak Republic.

- Ing. Petra Okrinova: University of Maribor, Slovenia.

Visits by foreign students to the AdMaS Center:

- Arnaud Chuter, FAYAT TP, Bordeaux, France: Laboratory and field testing of road materials.

- Riko Sakuda, YNU Jokohama, Japonsko: Urban roads and urban infrastructure.

- Ing. Martin Kotol, Ph.D., DTU Lyngby: Negotiations regarding closer cooperation in the area of R&D

Examples of cooperation with foreign research institutions and companies:

- OMV, AG, Austria: Evaluation of two experimental sections (Domasov, Lednice), and an analysis of the rheological properties of special asphalt binder PmB 45/80 RC four years after it was laid.

- Consultest AG, Switzerland: Measurement of the rheological parameters of 6 binders before ageing and after short–term artificial ageing (RTFOT), which simulates ageing at hot asphalt mixing plants, and long–term artificial ageing (PAV), which simulates ageing on roads.

- Oulu University of Applied Sciences Ltd – PaiBiRa: Testing, analysis and structural/physical evaluation of local building materials of biological origin from the area of Oulu – Finland.

- Within the framework of the national technological platform *"Interoperability of Railway Infrastructure",* cooperation took place with our Spanish partners from the Spanish technological platform PTFE (Spanish Railway Foundation, Technical Secretariat of the Spanish Railways Technological Platform).

- Membership in the EURNEX network: preparation of projects within the Horizon2020 and Shift2Rail programmes.

- Preparation of the Open Calls project (Open calls for non–members of Shift2Rail) 2019; participation in the consortium for project S2R–OC–CCA–01–2019 *"Noise & Vibration",* coordinator FIT Consulting srl, Italy (application submitted).

Research Group EGAR

Visits to institutions abroad:

- Assis. Prof. RNDr. Mgr. Lukas Krmicek, Ph.D.: Deutsches GeoForschungsZentrum Potsdam, Germany.

- Ing. Richard Slavik: KU Leuven, Faculty of Architecture, Belgium.

- Assis. Prof. Ing. Tomas Hanak, Ph.D.: STU Bratislava, Slovakia.

Mobility of staff from foreign partner institutions to the AdMaS Center

- Mihaela Pericleanu: Ovidius University in Constanta, Romania.

- prof. Ing. Milos Knezevic, Ph.D.: University of Montenegro, Montenegro.

- Ing. Joanna Cymerman, Ph.D.: Koszalin University of Technology, Faculty of Civil Engineering, Poland.

- Ing. Anna Cellmer, Ph.D.: Koszalin University of Technology, Faculty of Civil Engineering, Poland.

Examples of cooperation with foreign research institutions and companies:

- Slovak University of Technology in Bratislava – experimental BiPV (Building–integrated Photovoltaic) research into facade concepts enabling the storage of thermal energy while using latent heat. The output of this cooperation was a dissertation successfully defended by Ing. Jakub Curpek, Ph.D. at a partner institute, STU in Bratislava, Slovakia.

Research group MM (Mathematical Modelling)

Visits to institutions abroad:

- Ing. Ondrej Slowik: Hohai University Nanjing, China.
- Prof. Ing. Drahomir Novak, DrSc.: Hohai University Nanjing, China.
- Ing. Lukas Novak: Hohai University Nanjing, China.
- Ing. Michal Vyhlidal: Slovenia Nat. Building and Civil Eng. Inst., Ljubljana, Slovenia.
- Assoc. Prof. Ing. Stanislav Seitl, Ph.D.: Wroclaw University of Science and Technology, Poland.
- Assoc. Prof. Ing. Stanislav Seitl, Ph.D.: Ghent University, Belgium.
- Assoc. Prof. Ing. Stanislav Seitl, Ph.D.: Politechnika Koszalinska, Poland.
- Ing. Hana Simonova, Ph.D.: Technische Universitat Wien, Austria.
- Ing. Ondrej Slowik: Universitat fur Bodenkultur Wien, Austria.
- Assoc. Prof. Ing. Jan Elias, Ph.D.: RWTH Aachen, Germany.

Other examples of cooperation with foreign research institutions:

- Cooperation with Politechnika Koszalinska, Poland: experimental determination of material characteristics.
- Cooperation with BOKU, Vienna, Austria: 3D printing and numerical simulations of anchoring.
- Cooperation with Ghent University, Belgium: analysis of material properties using.

7.2.4. Research staff mobility: collaboration with industry partners

Research Group STC (Structures and Traffic Constructions)

- Ing. Lukas Janda – 1 FTE with the programme *„Knowledge Transfer Partnership OPPIK", „Reducing the costs of repairs and reconstructions of flat roofs and eliminating the effects of roofs on the environment during their operation",* ROMEX s.r.o, Adamov.

- Ing. David Beckovsky, Ph.D. – 0.3 FTE with the programme *„Knowledge Transfer Partnership OPPIK", „Reducing the costs of repairs and reconstructions of flat roofs and eliminating the effects of roofs on the environment during their operation"*, ROMEX s.r.o, Adamov.

Research Group EGAR

- Research Institute of Crop Production, v.v.i. – cooperation with EGAR RG researchers within the mobility of Ing. Vaclav Krejzar, Ph.D. in the area of defining a solution of a multidisciplinary grant project aimed at reducing the impact of water pollution by quarantine bacteria Ralstonia solanacearum using advanced oxidation and reduction technologies. At the same time, methodological procedures for treatment of water sources affected by biological pollution were discussed.

Research Group MM (Mathematical Modelling)

- Ing. Martin Lipowczan: Cervenka Consulting s.r.o., Prague.

- Ing. Michal Vyhlídal: Cervenka Consulting s.r.o., Prague.

7.2.5. Research activities of the RG2

Research Group STC (Structures and Traffic Constructions)

Examples of significant R&D outputs:

- **Structural alterations conducted to provide structural support to footbridge reg. No. L07 across the River Morava in Kromeriz**; Investigator: Assoc. Prof. Ladislav Klusacek; Client: The City of Kromeriz.
  From January till April 2019, the footbridge over the River Morava in Kromeriz underwent alterations which provided it with structural support following the collapse of a similar bridge in Prague – Troja. The designed measures were based on the conclusions of a diagnostic survey and involved the installation of new external cables under the existing footbridge. The external pre–stressing employed two cables (one on each side of the footbridge) placed approximately underneath the cable trays of the original load–bearing cables. The new tensioning cables are secondarily protected by a protective fairing made from corrosion–resistant 2 mm–thick sheet metal. The

area between the fairing and the individual monostrands are filled with self–compacting plastic concrete. A key part was played in the design of the structural support by static and dynamic analyses conducted using a detailed computational model created using ANSYS. The static analysis addressed, among other things, the assessment of the "emergency state" of the structure in the context of the ultimate limit state. The aim of the proposed structural modification was to prevent the sudden collapse of the footbridge structure, as was the case with the footbridge in Prague – Troja. Structural support via external pre–stressing under the existing footbridge using cables without cohesion will create a "safety net" that will catch fragments of material if the ultimate limit state of the current footbridge should be exceeded due to possible uncontrolled corrosion of the original load–bearing cables. This potential event should now manifest itself only in the form of excessive deformation, and not in the collapse of the footbridge into the River Morava. The solution has been registered as FCE invention and a patent for the protection of the utility model is currently pending (see Fig. 17)

Fig. 17: Photograph of the footbridge in Kromeriz

Important R&D projects with industry partners, and other activities:

Transport Structures division – Railway Engineering (ZEL)

- **TA CR TE01020168 – The Center for Effective and Sustainable Transport Infrastructure (CESTI)**, recipient Czech Technical University in Prague and BUT as a member of the consortium, see www.cesti.cz

- **Project S–CODE, Switch and Crossing Optimal Design and Evaluation (Optimum design and development of switches and switch structures)**
  Type of project: Horizon2020, Shift2Rail–RIA (H2020–S2RJU–OC–2016–01–2)
  Implementation period: 36 months
  Start of project implementation: November 1, 2016
  Funds: 4 999 771.25 EUR
  From which BUT was awarded: 318 235.00 EUR, i.e. 8 813 030 CZK
  Recipient: University of Birmingham
  Consortium: DT – Vyhybkarna a stroiírna, a.s., Ferrovial, Rhomberg–Sersa Rail Group, Rail Safety and Standards Board, COMSA, Loughborough University, Brno University of Technology, University of Pardubice
  The project focuses on the radical improvement of the construction of switches and crossings in accordance with TD3.2 (Technology demonstrator) – A new generation of

switches and crossings. The basic aim of the S–CODE project is to engage in research, development, validation and initial integration with regard to a radical new concept for the construction of switches and crossings. This has the potential to lead to an increase in capacity, reliability and safety while lowering investment and operating costs. The project will focus on the use of advanced diagnostic and monitoring systems, on the structure of the railway superstructure and substructure, and on the development of a new switch control system.
The project is being investigated within the framework of the Joint Undertaking Shift2Rail, open call S2R–OC–IP3–01–2016 – "Research into new radical ways of changing trains between tracks", and it will be coordinated together with the call for members S2R–CFM–IP3–01–2016 – "Research into an enhanced track and switch and crossing system", project IN2TRACK2.

- **Improvement of the technical and capacity parameters of the railway connection between the South Moravian and Lower Austrian regions (TRANSREGIO), ATCZ158TRANSREGIO, European Union** – Interreg 2014 – 2020, cross–border, international and transnational cooperation programmes, launch: June 1, 2019, end: May 31, 2021

Transport Structures division – Road structures (PKO)

- **TA CR: TH02030194 – Using a mixture of aggregates with different resistance to polishing in wearing courses provides satisfactory skid resistance properties to road pavements, improved road safety and economical utilization of natural resources.**
  This project focuses on the usage of aggregate mixtures with low and high PSV values in asphalt mixtures for wearing courses. The performed research included the design of several asphalt mixtures of the AC 11 and SMA 11 type with various contents of basalt and greywacke aggregate (fraction 8/11), out of which slabs were manufactured in a laboratory. Samples were taken from these slabs and the friction coefficient after polishing was measured. Subsequently, the FAP value was determined for the individual asphalt mixtures. Based on the measurement results it was decided that a test section would be constructed on the premises of an asphalt mixing plant. The FAP values, determined for samples from this test section, showed a similar progression to the samples from the lab–manufactured slabs. The SMA 11 asphalt mixture containing 34 % greywacke aggregate (fraction 8/11) was therefore selected for use on a real section of road. Samples will also be taken from this section for subsequent laboratory analysis, and friction coefficient after polishing will be measured alongside longitudinal friction coefficient using a dynamic measuring device.
  A comparison of the resulting values of the coefficient of friction after smoothing is shown in the graph (see Fig. No. 18).

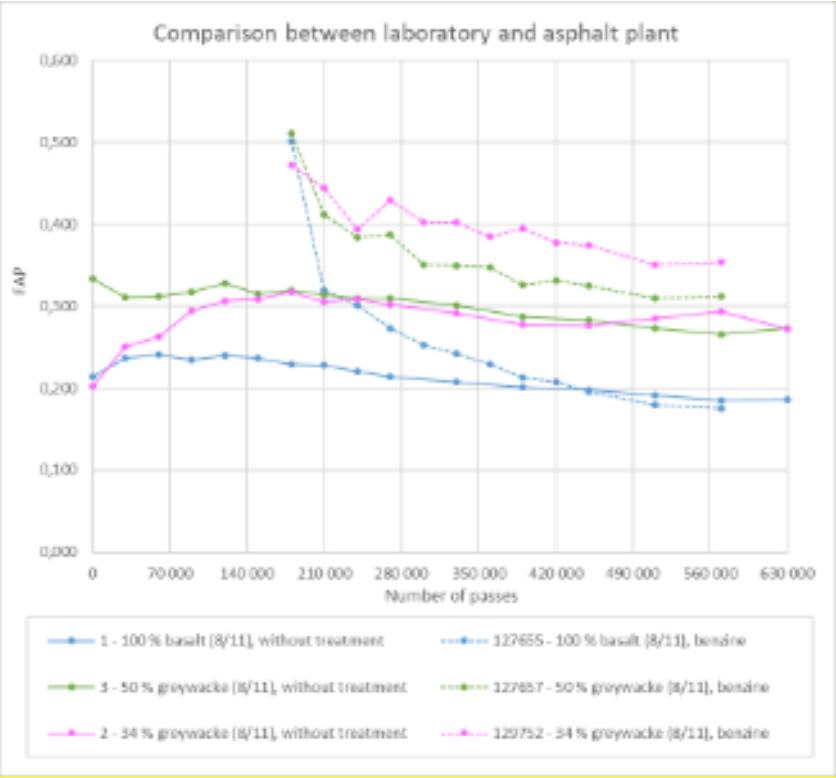

Fig. 18: Comparison of the progression of friction after polishing FAP in relation to the number of cone passes for an asphalt mixture of type SMA 11: test samples from a test section at an asphalt mixing plant (solid line) and test samples manufactured in a laboratory (dashed line)

Transport Structures division – Computer Aided Engineering and Computer Science (AIU)

- **The protection of soft targets in the security environment of the Czech Republic,** Security Research project for the Ministry of the Interior of the Czech Republic, implementation period: 2019 – 2022, co–recipients: Czech Technical University in Prague, Tomas Bata University in Zlin, VSB – Technical University of Ostrava, T–SOFT, a.s.
  The project focuses on comprehensive research and development in the areas of tools, analytical methods and software support for defining the protection of soft targets and assembly areas at the sector and municipal level. It responds to the fact that the security situation is deteriorating in terms of terrorism in Europe, where the great quantity of soft targets also creates the need for the transfer of responsibility for protection to departments, local governments and specific operators. The outputs of the project will provide a methodical and analytical background for this process.

Construction division – Concrete and Masonry Structures (BZK)

- **TH02020548 – Advanced assembled composite structures from pultruded profiles**
  Provider: TA0 – Technology Agency of the Czech Republic,
  Recipient: PREFA KOMPOZITY, a.s., Ing. Jan Prokes, Ph.D.,
  Co–recipient: BUT, Prof. RNDr. Ing. Petr Stepanek, CSc., Dr.h.c;
  Period of project implementation: 2017 – 2020
  The project focuses on the development and improvement of the utility properties of advanced assembled structures made from composite pultruded profiles and semi–

finished products. One of the aims was the design and execution of the connection (coupling) of composite bar cross–sections with a planar element (a reinforced concrete or hybrid slab). Loading tests were performed on the designed connection between the pultruded profile and the reinforced concrete segment of the slab (see Fig. No. 19 and 20) for the test configuration and achieved load–bearing capacity of three specimens). During year 2019 an experiment was conducted to verify the load–bearing capacity of the connecting elements under repeated loading.

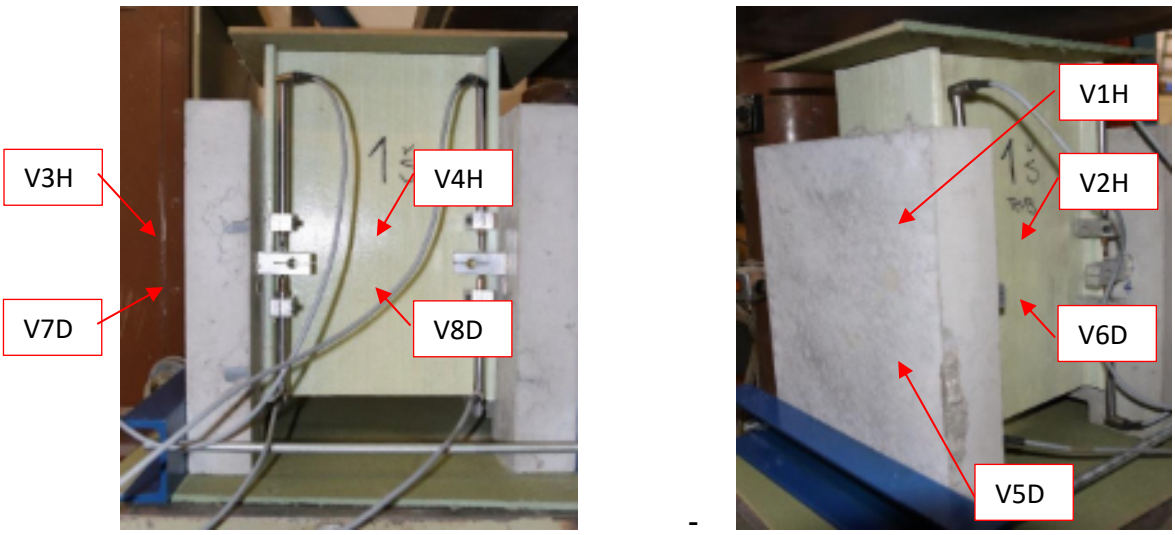

Fig. 19: Test configuration – connection using steel bolts, placement of test indicators

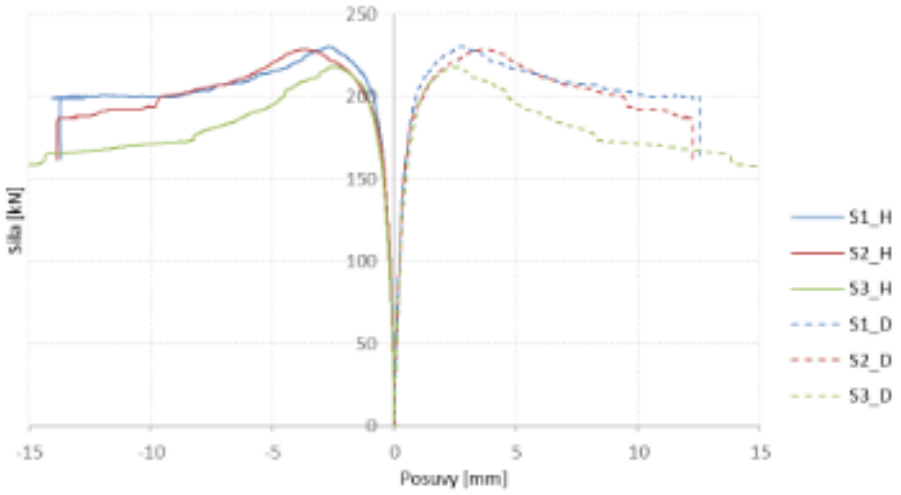

Fig. 20: Averaged displacement of beam flanges at the level of the upper bolts (H) and lower bolts (D) relative to the slab at the level between the bolts of samples S1–S3 (the sign convention corresponds to the elasticity convention: elongation = positive value, compression = negative value)

- **TH02020781 – Management of the reliability and lifespan of building structures in nuclear power engineering**
  Recipient: BUT, Prof. RNDr. Ing. Petr Stepanek, CSc., Dr.h.c;
  Co–recipient: Ustav aplikovane mechaniky Brno, s.r.o., Ing. Lubomir Junek, Ph.D.
  Period of project implementation: 2017 – 2019

The aim is to develop an applicable methodology for the comprehensive evaluation of the lifespan and reliability of built structures in nuclear power engineering (e.g. for accident localization shafts). It is a systematic process focused on the integration of the main activities of a nuclear power plant which affect the safety and lifespan of the structures at the plant. The evaluation method (NmetC) has been completed. Simultaneously, an application for the complex evaluation of the reliability and lifespan of a pilot structure of an accident localization shaft is being developed in cooperation with EDU.

- **FV10588 – A new generation of spatial prefabricates from high–performance concretes with increased mechanical resistance and durability**
  Recipient: Prefa Brno a.s., Ing. Michal Holak,
  Co–recipient: BUT, Prof. RNDr. Ing. Petr Stepanek, CSc., Dr.h.c;
  Period of project implementation: 2016 – 2019
  The project aims at the development of a new generation of spatial concrete prefabricates with significantly improved utility properties. During year 2019, among other things, a structure reinforced with standard concrete reinforcement was assessed via experiments alongside an alternative structure reinforced with composite GFRP reinforcement. The aim of the experiments was to assess the behaviour of construction details, in this case frame joints in various configurations with regard to the level of reinforcement of the structure, and its geometry. From the obtained data it can be stated that GFRP reinforcement is a possible alternative for the reinforcement not only of linear elements (slabs, beams) but also for such structural details (see Fig. No. 21).

Fig. 21: Load testing of frame corner elements

- **FV40278 – Resistant load–bearing sandwich elements made from advanced composite FRP materials**
  Recipient: PREFA KOMPOZITY, a.s., Ing. Jan Prokes, Ph.D.,
  Co–recipient: BUT, Co–investigator, Prof. RNDr. Ing. Petr Stepanek, CSc., Dr.h.c;
  Period of project implementation: 2019 – 2022
  The project aims at the area of research and development concerning a new generation of load–bearing sandwich elements made from advanced composite fibre–reinforced materials. It is expected that the structural design of the panels will feature a honeycomb core (a set of hollow cells created between the thin vertical walls of the

core) and a double–sided thin–walled sheath made from highly resistant composite glass fibre–based materials. Work on the project started on July 1, 2019.

- **TN01000056 – Advanced wood and composite structural elements for civilian buildings, (a sub–project within the framework of NCK CAMEB)**
  Companies and institutions involved: AGROP NOVA a.s., Kloboucka lesni s.r.o., PREFA KOMPOZITY, a.s, Brno University of Technology, FCE, BZK+KDK
  Period of project implementation: 2019 – 2020
  The part which is being investigated by the Institute of Concrete and Masonry Structures deals with issues concerning the behaviour of composite FRP materials under compressive stress in order to develop a compressed element made of FRP material as part of a set for the complete elimination of thermal bridges (transmitting compressive force) under environmental load.
  The first part of the research focuses on the determination of the basic short–term properties of the composite element under compressive loading. A set of test specimens made from prepreg designed for the production of mats was fabricated and tested. Prepreg is a material consisting of load–bearing glass fibres and a binder (polyester resin). It is used for the production of fibre composites. The resultant product is created by hardening the materials in a mould at increased temperature and pressure. The test configuration for short–term compression loading is shown in the image below ((see Fig. No. 22). In the second part of the research, issues concerning long–term behaviour under applied pressure are also being investigated. At present, a suitable solution for the configuration of the loading test has been designed and the production of the test apparatus is being arranged.

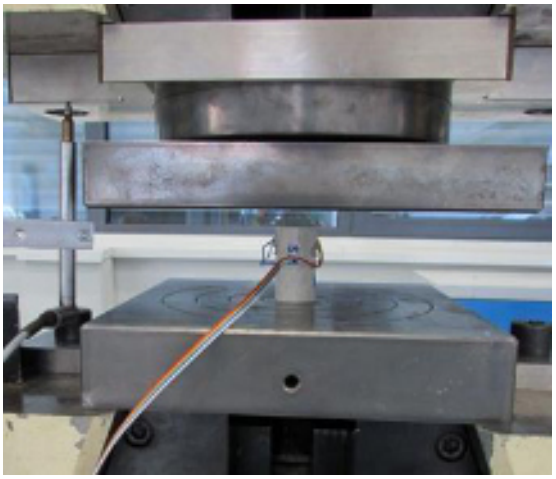

Fig. 22: Configuration for the short–term testing of FRP samples under compression loading

Construction division – Metal and Timber Structures (KDK)

- **MPO TRIO FV10317 – Advanced anchoring contact materials utilizing composites**
  The performance of laboratory tests on composite contact materials intended for application at temperatures close to 0°C. Creation of a functional prototype of recipe 531–AN2609 for this use. Creation of a verified methodology for testing specific mechanical properties of contact materials. Performance of long–term loading tests and tensile testing in high–strength concrete.

- **TACR TH02020301 – Advanced design for the reinforcement of loaded steel structures**
  The development of a software product has been completed. Completion of the validation and verification of numerical models. Basic commercial version of the product. Continuous publication of the results of theoretical and experimental research.

Transport Structures division – Building Structures (PST)

- **OP PIK CZ 01.1.02/0.0/0.0/16_054/0009229 – Reducing the costs of repairs and reconstructions of flat roofs and eliminating the effects of roofs on the environment during their operation**, ROMEX s.r.o, Adamov January 1, 2018 – May 31, 2019

- **TH04020263, Research and development for a system of cement and organic fibre–based structural composite slabs for timber structures and civilian buildings,** launch: January 1.2019 till 31, 2021

- **FV40357, Research and development for a new building material consisting of a composite sandwich slab for vertical vegetation structures**, in cooperation with TOPWET s.r.o.
  In the area of building construction, research is taking place with regard to the material properties of wood and the behaviour of wooden elements and structures. Also, research concerning energetically autonomous buildings (ENVIHUT) is taking place at the AdMaS Center site. The ENVIHUT has its own photovoltaic system and a wind turbine for the production of energy. Work is under way on research into the "Deformation of a non–stationary temperature field in the building envelope of houses covered by earth", as well as into a system of prefabricated vertical vegetation structures and a system of composite cement and organic fibre–based construction slabs for wooden structures and civilian buildings (see Fig. No. 23). The investigated projects are interconnected by their relevance to the topics of the circular economy and the use of recycled materials.

Fig. 23: Photograph of a green building at the AdMaS Center site.

Building Structures division – Technology, Mechanization and Construction Management (TST)

- **MPO TRIO FV10075 – A new technology for multi–storey energy–saving buildings fabricated from sandwich–bonded panels, with the option of founding on ground screws and using prefabricated sanitary core technology**
  The 6th stage of the project was successfully completed in March. It focused on the verification of the mechanical properties of sandwich construction panels. Subsequently, the 7th stage was completed in June 2019. This stage focused on the development of background materials for the design of multi–storey buildings. The 8th stage is the final stage of the project, which finished in December 2019.
  The project investigators are the companies EUROPANEL s.r.o. and Brno University of Technology's Faculty of Civil Engineering, specifically the Institute of Technology, Mechanization and Construction Management and the Institute of Building Structures.
  The main goal of the project is the development of a new production technology for multi–storey buildings based on the improvement of existing advanced EUROPANEL technology, i.e. a building system that utilises sandwich–bonded construction panels composed exclusively from rigid thermal insulation slabs clad with chipboard on both sides that is only 15 mm thick. It is a prefabricated, versatile, simple building system for the construction of energy–saving or passive timber structures.
  As part of the 7th stage of the project, a student competition was announced which involved creating a study of an apartment building with the name: EUROPANEL apartment building. The competing studies serve as background design material for the 8th stage of the project. A view of the apartment building proposed by the winning study is shown below (see Fig. No. 24). Furthermore, layout designs were created featuring a variable modular system; selected structural details considered to be at

increased risk of failure especially as a result of concentrated loading were statically assessed. The stage also included the thermal and humidity assessment of the structures of the future EUROPANEL apartment building and consideration of the options for using photovoltaic technology on the roof of the apartment block. At present, as part of the 8th stage, design documentation is being created for the construction of two apartment buildings, which are called “PUZZLE HOUSE” and “MONOBLOCK HOUSE”.

Fig. 24: Two views of the apartment building featured in the winning study from the competition: EUROPANEL apartment building (authors: Michal Knotek and Martin Pagáč – students at BUT)

- **MPO TRIO FV20606 – Technique for the bonding of large–format tiling elements**
  Project solver: Profibaustoffe CZ s.r.o. and Brno University of Technology, Faculty of Civil Engineering, TST Institute and SZK Institute.
  The 4th stage (testing of cement adhesives) was completed in April 2019. At the beginning of the year, the 5th stage was launched, which involves the testing of bonding mortars on ceramic tiling elements which interact with their base. The end of this stage was in October 2019. Together with this stage, the 3rd stage (testing of ceramic tiling elements) and the 6th stage (tests on construction models) were also under way(see Fig. No. 25). The project investigators are Profibaustoffe CZ s.r.o. and Brno University of Technology’s Faculty of Civil Engineering, specifically the Institute of Technology, Mechanization and Construction Management and the Institute of Building Structures.
  The main aim of the project was to develop a technique for bonding large–format tiling elements, i.e. tiling and floor tiles, using a thin–layer cement–based bonding mortar. Tiling and floor tiles have always had an irreplaceable position in the construction industry and the situation is no different today. The range of utility properties and advantages of ceramic tiles remain, but aesthetic demands are changing. At present a marked increase in the popularity of large–format tiles can be observed.
  For the purposes of this project, the term “large–format ceramic tiling element” is defined as a planar ceramic tile, usually made from sintered ceramic body, at least one dimension of which exceeds 1000 mm. These elements entered the market approximately 10 years ago in the 600 x 1200 mm x 8 mm and 600 x 1200 x 10 mm

formats. Today, products in the 800 x 1800 x 10 mm, 800 x 2400 x 3 to 6 mm and 1500 x 3 000 x 3 to 6 mm formats are appearing on the market ever more frequently.
The testing of ceramic tiling, which is part of the 3rd stage of the project, started in 2018 and has been continuing in 2019. The end of this stage was in October 2019. The properties of the tiling elements are being tested as part of this stage. The testing of the characteristics of cement adhesives has already ended. Tests have being carried out on structural models as part of the 6th stage. The production of panels with the dimensions 2.1 x 3.0 m is shown in Fig. 25. There are 24 panels in total.

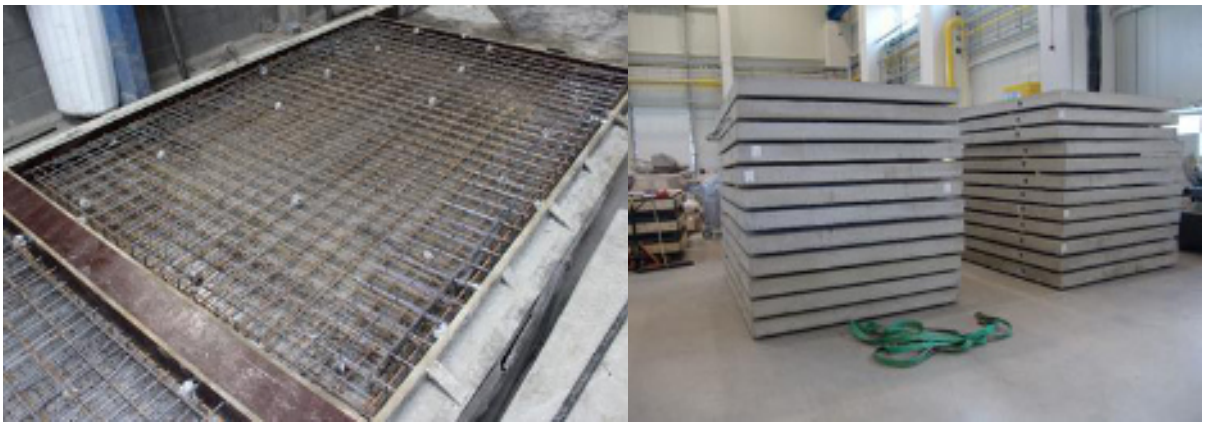

Fig. 25: a, Panel reinforcement *b, Storage of panels at the AdMaS site*

The gluing of the large–format ceramic tiles onto the panels took place directly next to the testing device in the hall at the AdMaS site. The gluing process is shown in Fig. 26. The resistance of the large–format tiling is tested using the surface loading method. A tested sample is shown in (see Fig. No. 26).

Fig. 26: a, Gluing of large–format ceramic tiles onto panels *b, Testing of ceramic tiles*

Construction division – Mathematical Modelling (MAT)

- In the reviewed period, the members of the MAT Research Group investigated theoretical issues related to the focus of the AdMaS Center. The research activities at MAT focused on the physical, mathematical and computational analysis of the appearance and propagation of cracks in quasi–brittle materials in cooperation with the Institute of Physics of Materials at the Czech Academy of Sciences. Attention was also paid to:

i, the mathematical description of phenomena using discrete equations which are obtained via the discretization of continuous equations;

ii, an analysis of the properties of the solutions of discrete and differential equations with delay (feedback), which are used to provide more accurate descriptions than standard differential equations. In the case of discrete equations, a solution for systems with a slight delay was found. The results have been published in articles in high–impact journals. Another article has been accepted for publishing in a high–impact journal.

- The framework cooperation agreement for 2019 between FCE BUT and the Institute of Physics of Materials at the Czech Academy of Sciences, v.v.i., concentrates on research into the mechanisms of failure of advanced building materials and structures with a particular focus on fibre composites. Selected preliminary results were presented at the MSMF conference (Materials Structure and Micromechanics of Fracture) in Brno, July 2019; the conference article was accepted for publication. Responsibility: Prof. Ing. J. Vala., CSc.

Research Group EGAR

In the area **"Measurement of the thermal and microclimatic properties of buildings and parts of buildings (including their properties with regard to exterior and interior conditions) with the aim of designing construction procedures and technologies for the production of construction parts to achieve, in particular, optimum energy and other parameters for structures**", the following activities took place in 2019:

- Membership in the Czech Smart City Cluster continues; support during the systematic introduction of the Smart City concept under the conditions of the Czech Republic.

- Research and expansion of the experimental base of outdoor test cells for verifying the behavior of BiPV façade structures with the integration of materials with a change of state in real outdoor conditions continues; Measurements are underway to verify long–term effectiveness on a year–round basis, and research in this area continues.

- Work continues on the project Intelligent Regions – Information modelling of buildings and urban areas, technology and infrastructure for sustainable development – project No: TE02000077. Development of activities at pilot locations in Nový Lískovec – development of an informational model https://smartcity.admas.vutbr.cz/.

- In 2019 a new research project began: TA CR TN01000024 – *„National Competence Center –Cybernetics and Artificial Intelligence"* – controlling a stable environment in the industrial halls of Industry 4.0.

- Contract research is being carried out concerning the conceptual design of energetically independent island structures, with a focus on water and energy management, and the comfort of the indoor environment. The extent of this research will be sufficient for future testing.

- In the area of the **"Development of new technologies in the area of drainage and wastewater treatment, the treatment of drinking water and its distribution, waste handling, the development of new procedures for the use of energy from**

wastewaters, waste and sludge created during the cleaning of wastewaters", the following activities took place in 2019:

- Contract research regarding the hydraulic assessment of the Znojmo city sewer network (Vodarenská akciova spolecnost a.s.).
  Equipment: Device for flow measurement in sewer networks, Mike URBAN software

- Contract research in the area of expert project assessment: Ensuring the capacity and quality of the Pardubice group water supply network – Part 1: Intensification of the Hrobice water treatment plant (Vodovody and kanalizace Pardubice, a.s.).
  Equipment: hall P4 at the AdMaS Center, the equipment of a stationary analytical laboratory for the assessment of urban engineering technologies

- Investigation of contract research: Monitoring of the city of Brno's sewer network for the purposes of analysing the substance load of the Brno–Modrice wastewater treatment plant – 2019; measurement of the hydraulic parameters of selected relief chambers.
  Equipment: Devices for flow measurement and the automated collection of samples, along with the measurement of the basic electrochemical quantities of wastewater in sewer networks and at wastewater treatment plants

- Development and design of technology for the decontamination of wastewaters from the manufacturing of cytostatic injections.
  Equipment: Pilot AOP unit, hall P4 at the AdMaS Center

- Contract research for the testing of double–walled piping as a part of safety measures for water management infrastructure, sewer network area.
  Equipment: hall P4; flow measurement equipment

- Publishing activities with various partners in areas defined by the TA

- Start of investigation of TA CR Zeta projects
  i, "Processing of gastro waste into the form of a solid carbon product for material use"; project identification number: TJ02000262

  ii, "The potential of torrefaction in the treatment of sewage sludge for further use"; identification number: TJ02000261¨

- "Acquisition and use of thermal energy from wastewater in combination with the use of purified water", identification number: TJ02000190.

- Start of the investigation of TA CR project "National Competence Center – Center for Advanced Materials and Efficient Buildings"; identification number: TN01000056
  Investigation of a subsidiary project: "Recycling of water and waste within green urban infrastructure"; reg. No.: TN01000056/03

- Contract research in the area of the microwave depolymerisation of waste materials with a focus on the processing of sludge from wastewater treatment plants and waste containing carbon.
  Equipment: hall P4 at the AdMaS Center, the equipment of a stationary analytical laboratory for the assessment of urban engineering technologies

- Contract research with companies and towns in the area of the optimization of wastewater treatment operations and the remediation of utility networks.

- Investigation of a number of Ministry of Industry and Trade innovation vouchers in areas such as safety measures for water treatment infrastructure, the use of treated sewage sludge as an alternative fuel in heating plant systems, a conceptual design for the incorporation of the microwave torrefaction of sewage treatment sludge into sludge management at a wastewater treatment plant, the creation of a conceptual design for an emergency supply of drinking water for inhabitants in a crisis situation.

- In the area "**Creation of geodetic, photogrammetric and metrological support for construction activities and research (the surveying of built and natural structures, the creation of 3D models from aerial and ground sensors – Lidar airborne scanner, ground scanners, camera arrays for use with bundle block adjustment, the determination of the exact geometry of individual elements, components, structures and buildings, calibration of small and large dimensions). Determination of the absolute spatial position of built structures and other structures, and the monitoring of short–term and long–term changes that affect them using global navigation satellite systems (GNSS – GALILEO, GPS, GLONASS)"** the following activities took place in 2019:

- Investigation of specific research project FAST–S–19–570 "Geometric accuracy of mobile mapping systems". Involvement of Geodesy and Cartography students in AdMaS Center research activities. The project focuses on the optimization of mobile mapping methods: the main focus is on methods of data acquisition and evaluation with regard to the geometric accuracy of the result and the complexity of the whole process. For this purpose, a network of ground control points and checkpoints was created and positionally determined. The checkpoints are evaluated for the analysis of external effects. The determination of the accuracy of the carrier's trajectory is also subjected to analysis.
  Equipment: system of generally oriented images, mobile mapping system, portable mapping system, disc array, the AdMaS Center site with regard to the installation of ground control points

- The further development of activities for the creation of strategic decision–making methods using GIS tools in connection with activities launched in 2018. Research activities were underway with regard to the automation of the creation of outputs from mobile mapping data (images and point cloud) and the use of laser scanning for the creation of construction drawings and BIM. These activities were carried out both during the preparation of diploma theses and as part of contract research.

- In the area **"Verification of the practical applications of field and laboratory measurements, the evaluation (including mathematical modelling) and development of methodologies in the field of geotechnical research methods, and the diagnostic analysis of the foundation conditions of structures, both from the aspect of designing structures and of their remediation and lifespan analysis"**, the following activities took place in 2019:

- The start of the implementation of TA CR project "National Center of Competence – Center for Advanced Materials and Efficient Buildings"; reg. No. TN01000056
  Implementation of a subsidiary project: "Optimization of energy piles to use energy from the ground"; reg. No. TN01000056/06

- Rock testing: numerous samples of greywacke, sandstone, breccia and (to a lesser extent) other types of rock were tested.

- Testing of cement pastes

- Implementation of project FAST–S–19–5724. The improvement of soil by means of scattered reinforcement (micro–reinforcement) represents a modern trend in geotechnical engineering. This type of ground treatment provides an alternative to surface reinforcement via geosynthetics (e.g. geogrids), which can be technically demanding. In practice, straight micro–reinforcement with a smooth unstructured surface is usually used, which reduces the level of interaction between the micro–reinforcement and the soil. The essence of the proposed project is to use advances in 3D printing technologies for the development of a more efficient shape and surface for scattered reinforcement.
  Equipment: hall P4; automated triaxial system and consolidation system

- Implementation of project FAST–S–19–6031. The principles of fracture mechanics can be applied to rocks. They can explain the process of rock specimen failure in laboratory tests and in geomechanics applications. A study will be made of greywacke, whose properties may vary within a single locality. The cooperation of experts from the fields of rock mechanics, fracture mechanics and building testing will enable a comprehensive approach to the testing and evaluation of rock fracture parameters. Petrographic description and other mechanical tests enabling the analysis of factors influencing the resultant behaviour of rock will be added.
  Equipment: hall P4; Automated triaxial system and consolidation system

Examples of R&D activities in 2019:

- Rock testing (see Fig. No. 27 – 30): Numerous samples of greywacke, sandstone, breccia and (to a lesser extent) other types of rock were tested with regard to transverse tensile strength and uniaxial compressive strength. In the compressive test, the relative deformation of samples was measured using resistance strain gauges. Based on the data obtained, the deformation behaviour typical for a particular rock can be characterized – the properties of the individual rock types were compared. The analysis was extended further to cover the individual components of deformation (axial, radial and volumetric), which can be used to identify the individual phases of rock failure. It is common to analyse axial strain only, but this is much less sensitive to certain aspects of specimen failure under uniaxial pressure.

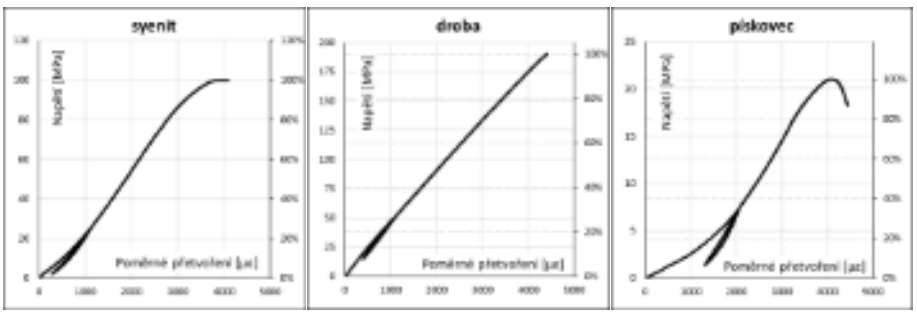

Fig. 27: Stress–strain diagrams for different types of rock – comparison of the characteristics of deformation behaviour typical for individual types of rock

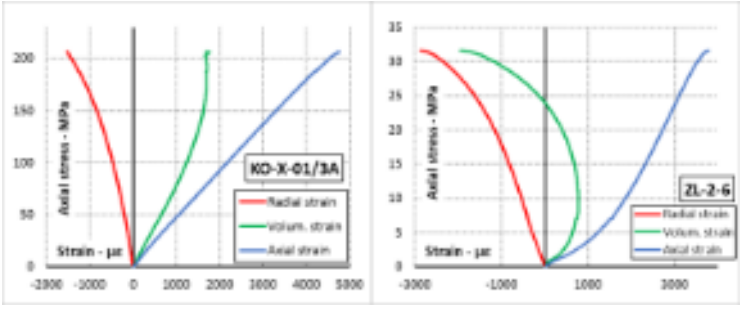

Fig. 28: Examples of extended stress–strain diagrams of rock with the addition of radial and volume deformation components. Left – greywacke, right – sandstone.

Fig. 29: Example of sandstone with installed resistance strain gauges after failure during uniaxial pressure testing.

Fig. 30: Examples of greywacke samples after uniaxial pressure testing. The tests focused on verifying the effect of rock compression strength in relation to the height/diameter ratio of the element (L/D).

- Testing of cement paste: Testing of the uniaxial and triaxial compressive strength of cement paste for anchor grouts. The measurements from the tests were used to determine the values of failure condition parameters

- Continuation of the implementation of project TACR TE02000077 – Intelligent regions – information modelling of buildings and urban areas, technology and infrastructure for sustainable development. 2019 saw the implementation of the verified technology SW REGIOS – a software tool for the management of heating plant systems (see Fig. No. 31). Furthermore, issues connected with building information modelling (BIM) were also investigated, particularly with regard to the process of describing and modelling current buildings. In the course of work being carried out on a Diploma thesis, an information model of building A05 at the BUT Pod Palackeho Vrchem student residence hall site was created using laser scanning technology (see Fig. No. 32).

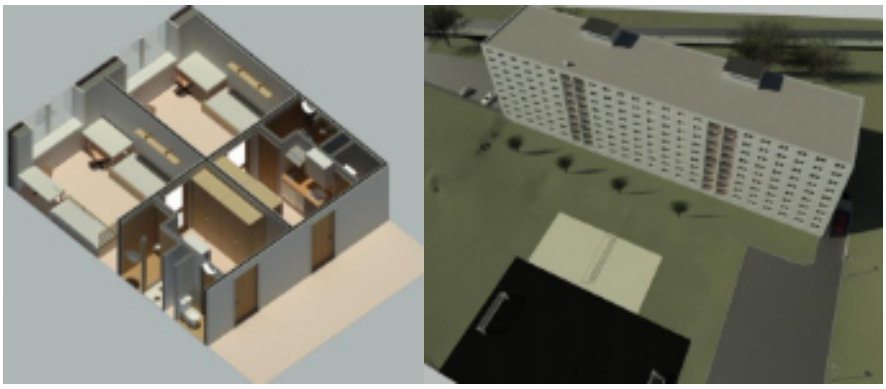

Fig. 31: Visualization of the interior and exterior spaces of the BIM model of student residence hall building A05, BUT

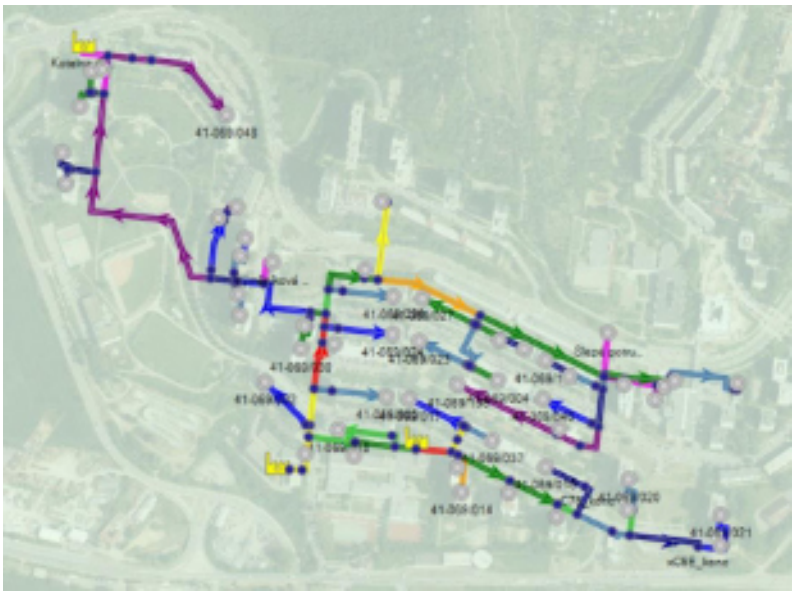

Fig. 32: SW Regios – an example of outputs – graphical representation of velocity in piping

Examples of collaboration with industry partners on R&D and contract research projects:

- Brnenske vodarny a kanalizace, a.s.; Monitoring of the sewer network of the city of Brno in order to enable the analysis of the material load of the Brno–Modrice wastewater treatment plant – 2019; monitoring of the hydraulic parameters of selected relief chambers (see Fig. No. 33).
  Equipment: devices for flow measurement and automated sample collection, as well as for the measurement of the basic electrochemical quantities of wastewater in sewer networks and at wastewater treatment plants

Fig. 33: Collection of samples from automated ISCO samplers; flow measurement in integrated sewerage systems

- Vodarenská akciova spolecnost Znojmo, a.s. – continuation of contract research – creation of a hydraulic model of a sewer network. The model was calibrated and verified according to values measured in 2018 and technical measures were proposed to improve the operation of the sewer network (see Fig. No. 34 – 36).

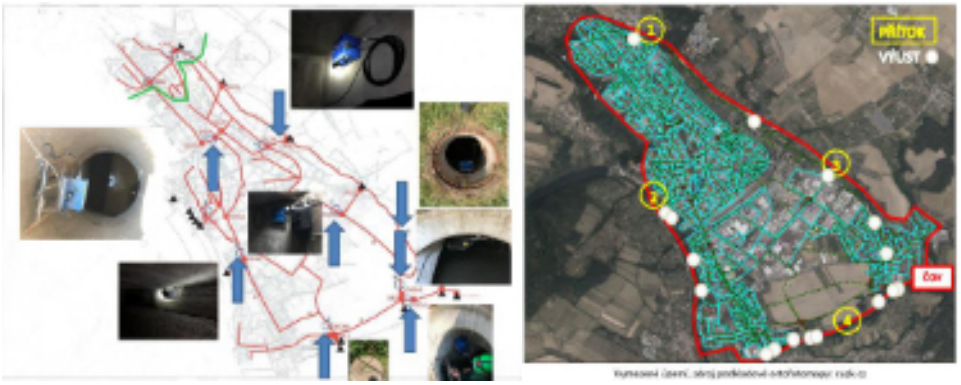

Fig. 34: Hydraulic model of the sewer network in Znojmo

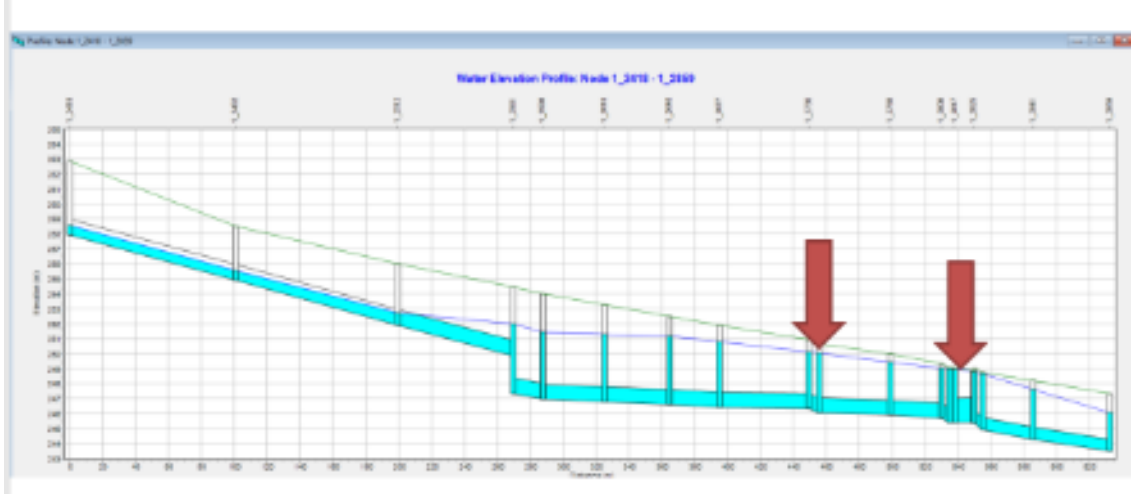

Fig. 35: Hydraulic model of the sewer network in Znojmo

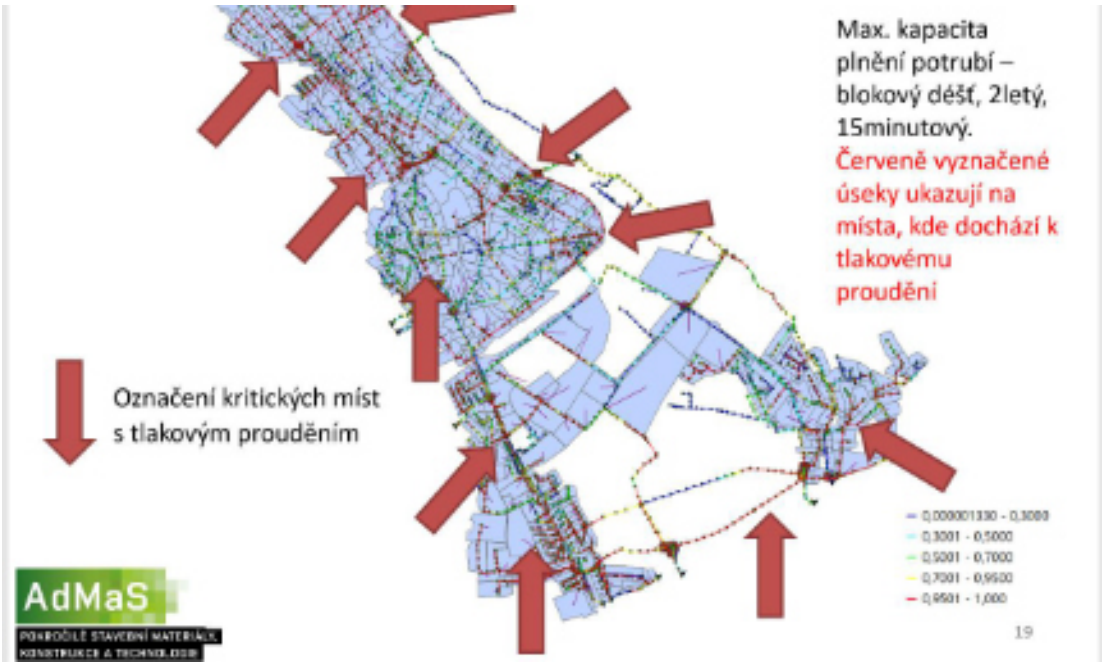

Fig. 36: Hydraulic model of the sewer network in Znojmo

- In the area of contract research, an expert assessment of the project below was carried out: Ensuring the capacity and quality of the Pardubice group water supply network – Part 1: Intensification of the Hrobice water treatment plant – research report SR12957046. A unique newly designed water treatment technology was evaluated and the costs were assessed.

- Vodovody a kanalizace Kromeriz a.s. – contract research in the area of hydrotechnical evaluation using either the dynamic hydrological–hydraulic simulation model SWMM (Storm Water Management Model) or the MIKE URBAN model (see Fig. No. 37). Equipment: software for the analysis of water, sewer, wastewater treatment plant

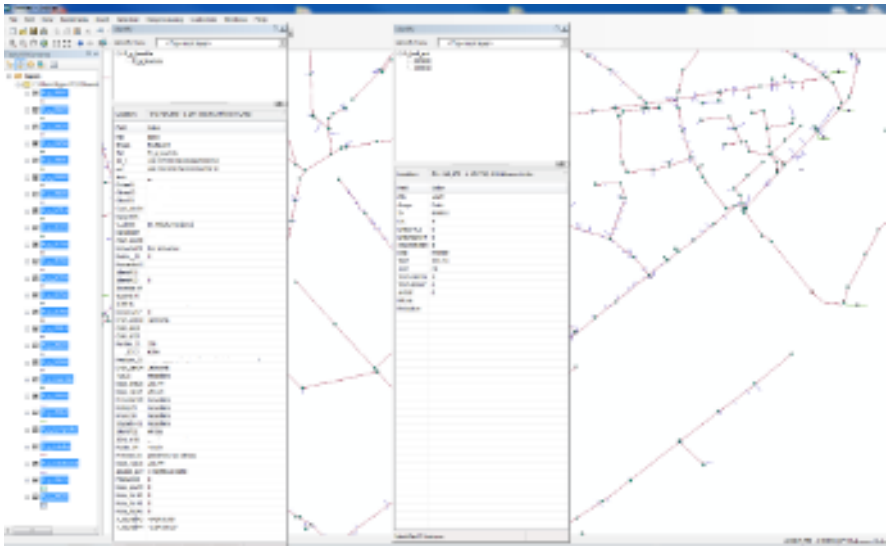

Fig. 37: Hydraulic model of the sewer network in Znojmo

- In cooperation with Brnenske vodarny a kanalizace a.s., laser scanning was performed on a waterworks structure and a web application was created showing the depicted object in the form of a 3D laser cloud of points supplemented with panoramic images and descriptive information on the individual technological elements (see Fig. No. 38). In 2019, research activities will continue in the form of information modelling and the creation of BIMs of current water management structures. Geodesy and Cartography students working on their diploma theses will also be involved.

Fig. 38: Demonstration of the publicising of point clouds via the ground laser scanning of a water tower

Research Group MM (Mathematical Modeling)

Examples of significant R&D outputs:

The MM group has been cooperating with other RGs on a long–term basis, providing theoretical and numerical tools for the fulfilment of the more practically oriented goals of individual RGs. This cooperation continued in 2019.

The goals of the RG MM, which were successfully achieved independently in 2019, are as follows:

- the development of an efficient method for the determination of the reliability of buildings,
- development in the area of nonlinear fracture mechanics of the continuum and fracture process zone,
- determination of the fracture mechanics parameters of quasibrittle materials (concrete, fibre concrete) on the basis of experimental/computational procedures.

Examples of R&D activities:

The research activities of the MM team included several subsidiary topics concerned with issues affecting buildings. The following items provide a description and examples of research activities carried out by the MM RG.

- The research activities of the part of the team devoted to fracture mechanics were primarily focused on the deepening of selected aspects of fracture experiments, and the evaluation and numerical simulation of such experiments. The primary fracture test configuration used was the 3–point bending test, which was applied to specimens with a notch–type stress concentrator at the location where the fibres are in tension (3PB). As far as the specimens are concerned, these were most frequently beams with a standard straight notch, cylindrical elements with a Chevron notch (arrow notch) and a newly tested configuration of semi–circular elements with an initial notch made at various angles, for which silicon moulds were produced (see Fig. No. 39).

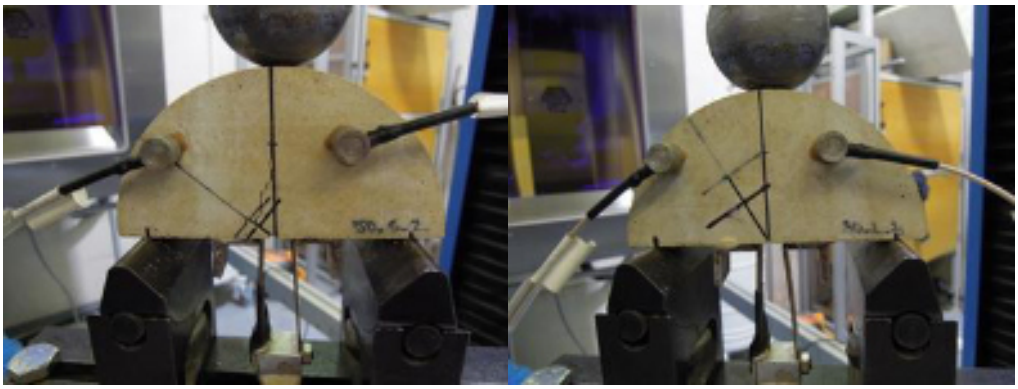

Fig. 39: Images from the 3–point bend testing of a semi–circular element with an initial notch made at various angles: 50°, short notch (left) and 30°, long notch (right).

- Another fracture mechanics experiment was the testing of Brazilian disc–type test specimens in two variants:

  i, without a notch (to determine indirect transverse tensile strength)

ii, with a notch (to determine the behaviour of a specimen stressed in the combined mode). The materials examined were mainly high–performance concretes (HPC), which could be suitable replacements for current mixtures, see publication.

In accordance with current and planned experiments, numerical simulations were carried out using the concrete damaged plasticity (CDP) model with the aim of mutually comparing the achieved results with those from fracture tests. An example of a Brazilian disc–type element is show below (see Fig. No. 40). Attention was paid to (among other things) the study of the direction of crack propagation in samples loaded in the combined mode. Various configurations were compared, and the influence of the members of higher orders on the estimate of the resultant angle under which the crack will propagate from the initiation notch was tested. The results were published in a journal.

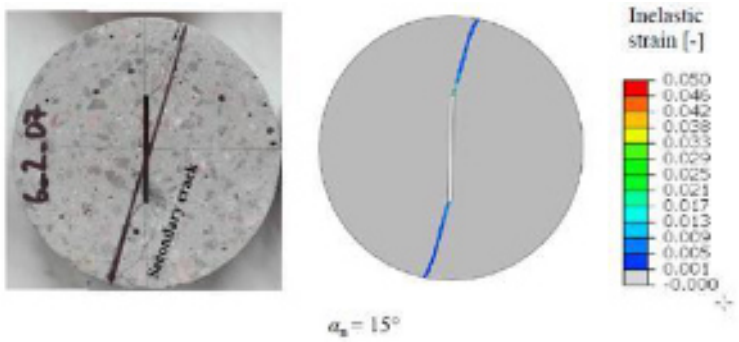

Fig. 40: An experiment with a Brazilian disc–type specimen: a real sample with a notch at 15° (left); FEM simulation to determine the direction of crack propagation (right).

Attention was also focused on the identification of fracture mechanics parameter values – static modulus of elasticity, tensile strength and specific fracture energy – using records from performed tests in the form of force versus displacement diagrams – bending at midspan (see Fig. No. 41). Additionally, the contribution of alkali–activated matrix to the fracture response of composites with various contents of steel wires was quantified. The results were published in a journal.

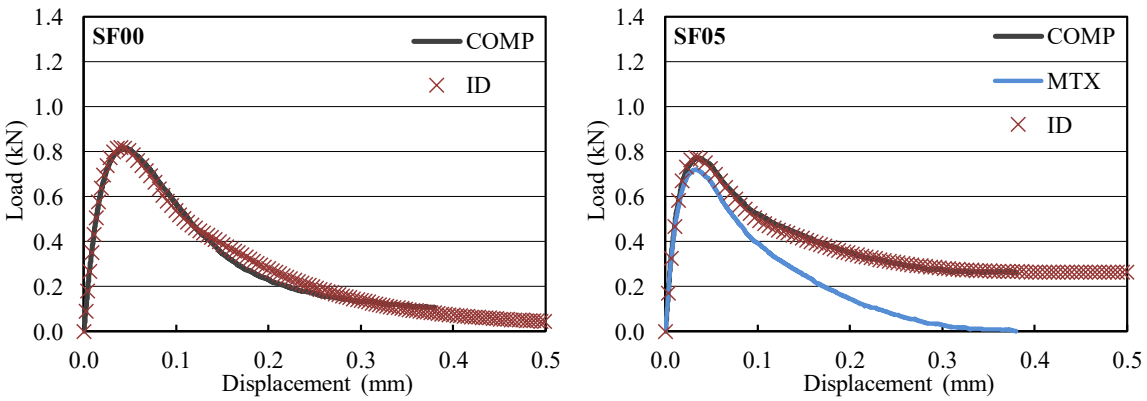

Fig. 41: Force vs. displacement diagrams: selected records from an experiment (COMP) and a numerical simulation (ID); the contribution of alkali–activated matrix (MTX) is shown on the right.

Another of the investigated topics was the effect of thermal loading on the properties and internal structure of a selected material. Test specimens with dimensions of 20 x 40 x 200 mm were prepared from a specially designed cement–based fine–grained composite. The fresh mixture was produced using a spherical sodium–potassium glass filler with a diameter of 2 ± 0.2 mm, Portland cement CEM I 42.5 R (Mokra cement plant) and water in the ratio 3 : 1 : 0.35. After the samples had been poured into the prepared silicone moulds and compacted, they were left covered by PE foil for one day and subsequently stored in water for 28 days. The mature samples were loaded with high temperatures using a Classic 5013 laboratory oven. For the purposes of X–ray, CT and 4D CT scanning, in combination with four–point bending, one test specimen was produced for each of the following temperatures: 100 °C (reference sample), 200 °C, 400 °C, 600 °C, 800 °C and 1000 °C. The thermal loading started at a temperature of 20°C and increased at increments of 5 °C/min until the achievement of the set maximum, which was then maintained for a further 60 minutes. After the samples had cooled to room temperature, they were kept at a constant 20°C. The samples exposed to temperatures above 200 °C suffered too much damage and could not be tested in four–point bending. The specimens exposed to 100 °C and 200 °C were subjected to this test, however.

The decrease in the mechanical parameter values and the damage to the internal structures of the specimens exposed to temperatures of 100 °C and 200 °C were monitored using a new method combining the four–point bend test and computed tomography. The majority of samples exposed to higher temperatures were damaged to such a degree that they could not be subjected to four–point bending. For these samples, only the image–based information provided by standard computer tomography was evaluated, and the relationship between compressive strength and maximum applied temperature was confirmed. An example of the visualization provided by a selected tomographic section is shown below (see Fig. No. 42).

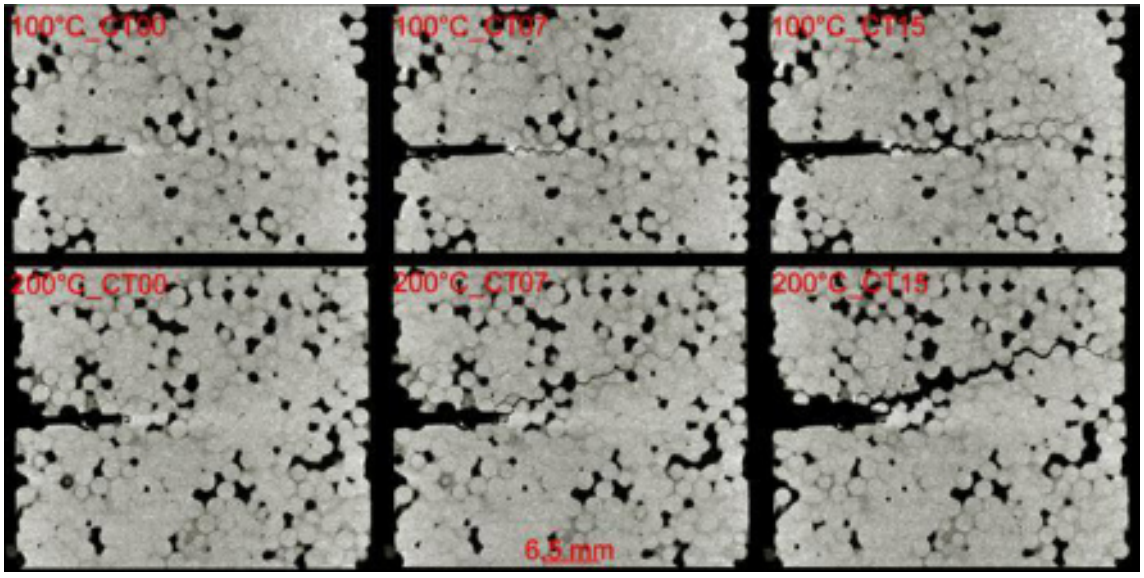

Fig. 42: Example of the visualization provided by a selected tomographic section during loading. The development of a crack in a specimen exposed to a temperature of 100 °C is shown in the upper images; the lower images show crack development in a specimen exposed to 200 °C.

Fractal dimensions of fracture surfaces were analysed for the concrete test specimens exposed to high temperatures. The test specimens were obtained from experimental concrete slabs after the execution of fire tests. The oven upon which the panels were

unilaterally exposed reached nominal maximum temperatures of 550, 600, 800 and 1000 °C. Also, reference elements from panels unexposed to fire load were tested. Specimens with nominal dimensions of 100 × 100 × 400 mm and a 33 mm central notch were tested in three–point bending; load versus displacement diagrams were recorded, corrected and evaluated. Each set contained 4 specimens and a total of 20 specimens were evaluated. Basic fracture mechanics parameters were determined: elasticity modulus, effective fracture toughness and specific fracture energy. The fracture surfaces (ligaments) of all the tested specimens were analyzed in detail after the bending tests. The ligaments were scanned using a 2d laser profilometer, and the fractal dimensions of selected parts of these fracture surfaces were measured, with the circumferential method being used for estimation. Correlation rates between the fractal dimensions, the temperatures in the concrete at different distances from the fire–loaded face and the measured fracture mechanics parameters were determined.

- Another main topic is the study of the elastic behaviour of discrete (or also lattice) models (see Fig. No. 43). These models are used in simulations of the inelastic behaviour of heterogeneous materials, where they can easily demonstrate phenomena that are very difficult to capture with other types of models. On the other hand, they have a major drawback in the elastic region, as a Poisson number higher than 0.25 cannot be achieved with them, and this is insufficient for many materials. Scientists from around the world have published several articles showing how this limit can be circumvented. Unfortunately, although the published procedures have the ability to represent higher Poisson numbers, they have all lost some of the essential features of the model when it comes to inelastic areas.
  The MM division tried to solve this problem by changing the geometry of the model. Typically, such models are constructed so that the normal vector at the contact between two discrete units is parallel to the direction of contact. Relations describing the dependence of Poisson numbers on the deviation of the normal and contact vector were successfully derived via homogenization. Unfortunately, these relations show that the borderline value of Poisson numbers decreases further when parallelism is lost. From this perspective, the best possible discrete model is one in which the geometry is composed in such a way that the parallelism of the described vectors is maintained. Even though the result didn´t lead to a solution of the problem, the analytical description of the situation and the proof of the impossibility of extending the Poisson number using geometry is a valuable result which will be sent to a foreign high–impact journal for review.

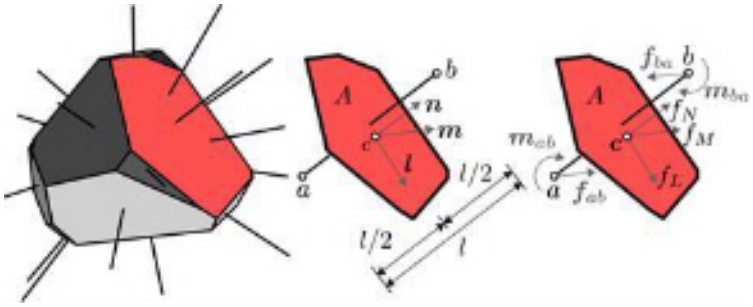

Fig. 43: A rigid body of irregular shape created by random Voronoi tessellation – the discrete model is created by combining a large number of such elements using contacts, one of which is highlighted in the image in red.

- Among the other theoretical topics investigated by the MM group is metamodelling, i.e. the creation of replacement models and their use in the sensitivity analysis of structural parameters. As part of this topic, an investigation was conducted into the use of a spectral projection technique of the Polynomial Chaos Expansion type (PCE, see Fig. No. 44) for global sensitivity analysis independent of statistical moments. Several initial studies were performed with very good results and a computational algorithm was developed which is able to automatically create and analyze PCE with regard to sensitivity analysis – i.e., the estimation of probability functions and calculation of their distance according to Cramer–von Mises, (see Fig. No. 45), where this distance (in the integral form) is shown in grey. This approach provides robust and effective quantification of the effect of input value uncertainties on the results of the mathematical model. In the next stage, several studies will be carried out focused on the influence of the correlation of input quantities and the nonlinearity of the mathematical model. Simultaneously, publication of the results is being prepared in the form of a specialized article.

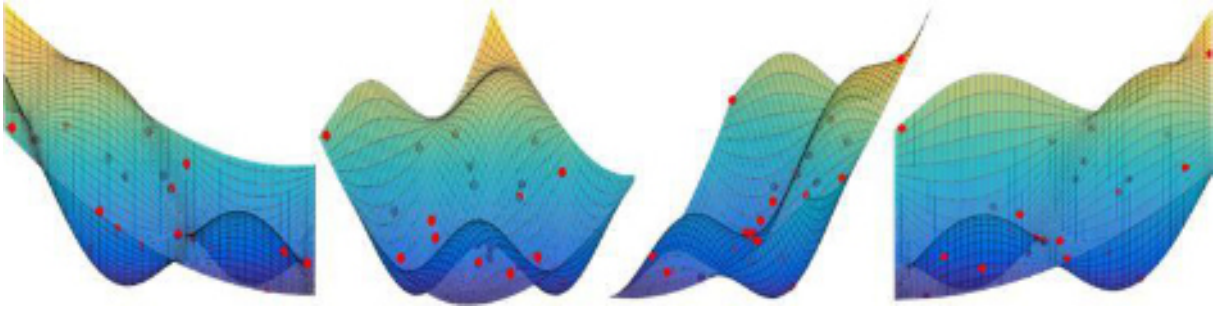

Fig. 44: Demonstration of the creation of an approximation (a metamodel) in the form of the Polynomial Chaos Expansion.

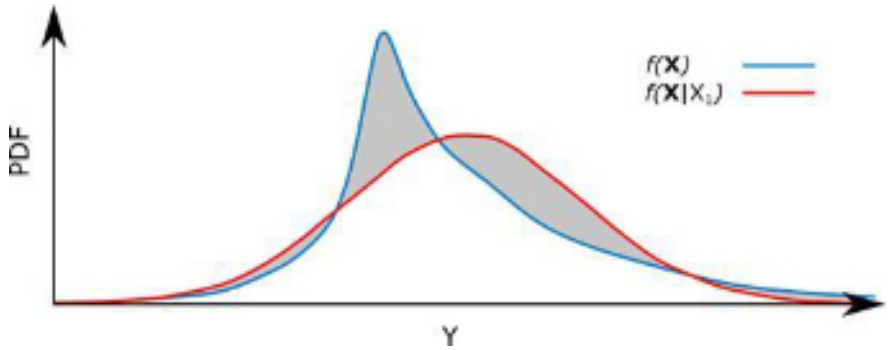

Fig. 45: Comparison of probability functions according to Cramer–von Mises.

- Another investigated theoretical area was the stochastic analysis of the propagation of fatigue cracks and limit states of steel bridge elements exposed to multiple repetitive loads from the passage of vehicles. The random quantities which are the most important for the occurrence of failure were identified with the help of a new type of sensitivity analysis that measures sensitivity with the help of what are known as contrast functions. The analysis proved the great effect of equivalent stress amplitude on the probability of failure. It demonstrated that a small change in the mean value or

standard deviation significantly affects the probability of failure and thus also the residual lifespan of a load–bearing bridge structure. At the beginning of the bridge operating period, the equivalent stress amplitude strongly interacts with other quantities, and particularly with an initial surface crack, while failures are derived in particular by extreme equivalent stress amplitudes in combination with relatively large initial crack values. Towards the end of the operating period, interaction effects weaken but the main effect of the equivalent stress amplitude, which remains the dominating quantity throughout the whole operating period of the bridge, strengthens. Particularly at the end of the operating period, the lifespan of a bridge can be increased very efficiently by limiting the passage of extremely heavy vehicles.
Based on these sensitivity analysis results, a detailed identification of the random variability of the equivalent stress amplitude was performed. In one case study [9] a methodology was described which reflects the uncertainties associated with load history and identifies the values of the variation coefficient of the equivalent stress amplitude. The case study showed that the uncertainty of the equivalent stress amplitude can be modelled with a coefficient of variation of 0.05 to 0.1, while the variation coefficient can be increased in relation to other uncertainties in the monitoring programme which were not addressed in the study.

- Part of the MM team continued studying the degradation of structures due to the effects of concrete carbonation and the penetration of chlorides, with a focus on reinforced concrete bridges in the Czech Republic. The degree of concrete carbonation (which can be estimated by measuring the pH of the concrete) and the amount of free chlorides in the concrete (determined from drilled concrete specimens via leaching) were monitored. Both phenomena need to be considered together when assessing a structure, which currently is not a common practice. “Critical areas” most affected by degradation were located on the selected bridges. For this purpose, a total of 5 bridges were examined, from which a total of 80 boreholes were selected, and from these 218 analyzed samples. Four of the bridges are located above a river or other water source, and one of them is over a road. The bridges above water have a higher supply of moisture, which increases the degree of carbonation. The bridge above the road has an increased supply of chlorides from road salt applied in the winter to the road beneath it.
  A summary of the measurements obtained for the individual bridges was created. For the purpose of identifying the so–called “critical areas”, we divided the individual structural elements of the bridges into 4 groups. Each group always contains elements which are expected to have a similar exposure to degradation effects. As an example, Fig. No. 46 shows the result when the joint effect of carbonation and the influence of chlorides is considered for the individual bridges and structural elements. The individual groups of elements are colour–coded in the picture, the age of each bridge at the time of sample collection is stated above it and the dashed horizontal line represents the critical value of the parameter.

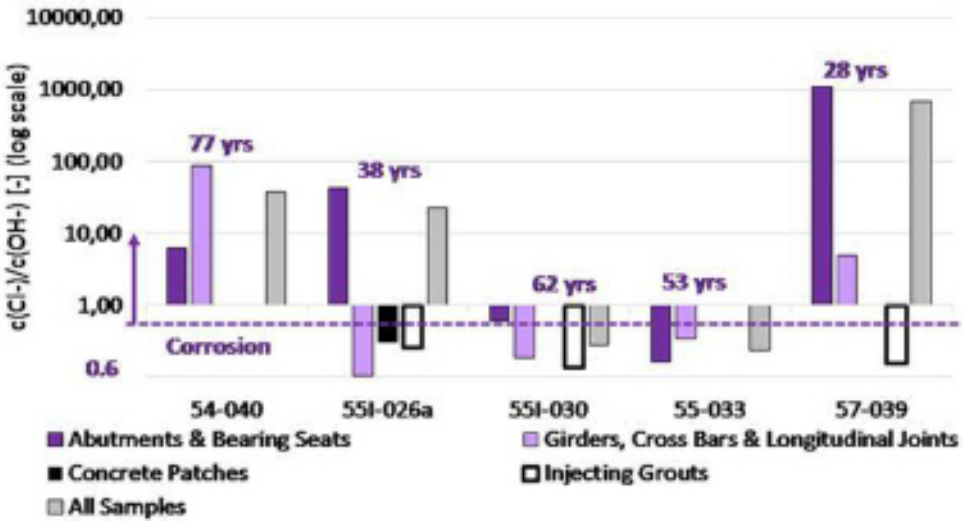

Fig. 46: The combined effect of carbonation and chlorides via the ratio c(Cl–)/c(OH–) for individual bridges and individual structural elements (average values).

Information on the use of purchased scientific equipment

The research division MM used the following purchased scientific equipment:

An Aramis instrument for the measurement of 3D deformation

A device for the measurement of 3D deformation was used for the evaluation of bending tests performed on beams made of plain concrete and on concrete reinforced with dispersed non–metal reinforcement as part of practical lessons in the subject CD055 Selected Chapters of Structural Mechanics (See Fig. No. 47).

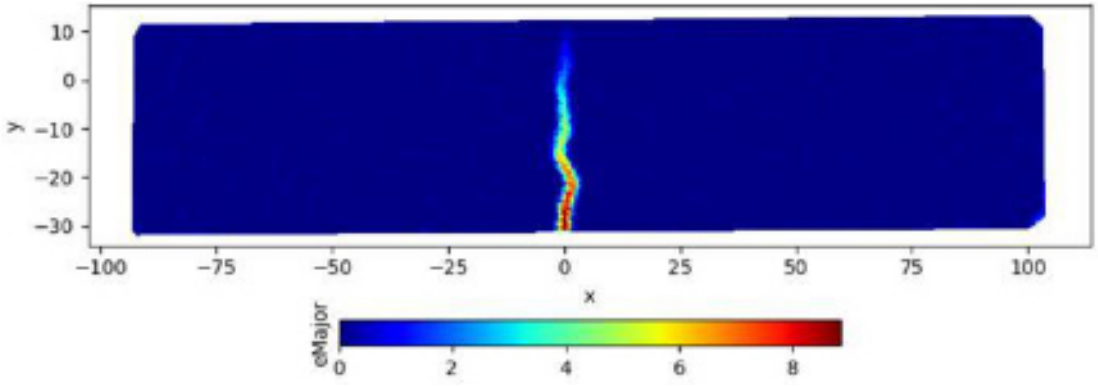

Fig. 47: Use of the Aramis instrument during the testing of bent beams fabricated from concrete reinforced by dispersed non–metallic reinforcement.

Computating

Computational equipment was used to conduct numerical analyses when investigating subsidiary research topics. For example:

- The generation of designs using a method that creates a set of representative points called Support Points using the R programming language.
- The development of a new algorithm for use in searching for the design point and interface between the failure area and safe area in engineering tasks with random input variables.
- A discrete particle model for the investigation of material fatigue – compilations and calculations.
- The web application Jupyter notebook – test notebooks for dealing with subsidiary problems during individual projects (fatigue, the combined role of mechanics and transport phenomena, design of experiments); online access to a database of designs and interactive work with results.

3D printer

The device was used to print spatial materials in the context of additive manufacturing and construction (See Fig. No. 48). It was also used to create surfaces designed using generative design methods such as topology optimization, multi–level optimization and periodic minimal areas, which are examined from the aspect of their possible use as 3D fills instead of conventional 2D (or 2.5D) fills. Due to double curvature and other properties which are advantageous from the mechanical point of view and for other reasons, light and solid structures can be produced whose geometrical complexity does not result in extra cost in the case of additive production.

Fig. 48: A spatial material – a cylinder damaged during a pressure test.

Examples of collaboration with industry partners on R&D projects and contract research projects:

In 2019 active contracts for collaboration existed between the RG MM and the following companies: (i) FEM Consulting, s.r.o., (ii) Ing. Pavla Busina's Design Office, (iii) COMET OBALY, s.r.o., (iv) Cervenka Consulting s.r.o. and (v) Moravia Consult Olomouc a.s.

- For example, a viscous nonlinear material model of concrete is being developed in cooperation with FEM Consulting, s.r.o for inclusion in RFEM calculation software. Its development is motivated by the need to faithfully simulate the response of concrete and reinforced concrete structures to very fast dynamic loading accompanied by an increase in the tensile and compressive strengths of materials, thereby increasing the overall rigidity of structures. The development includes experimental research into the response of reinforced concrete beams exposed to impact loading by steel drop weight in order to determine unknown values of the viscous parameters of the model (see Fig. No. 49). The beam's response was measured using conventional strain gauges and accelerometers and the whole experiment was recorded on camera at a rate of 1000 frames per second. The measured vertical acceleration values were then compared with the result of the software analysis of a slow motion video. Details about the experiment and a comparison of the conventional measurements with the video analysis and a simulated specimen response are summarized in a contribution to the SPACE international conference held in the High Tatras, the proceedings from which will be published this autumn.

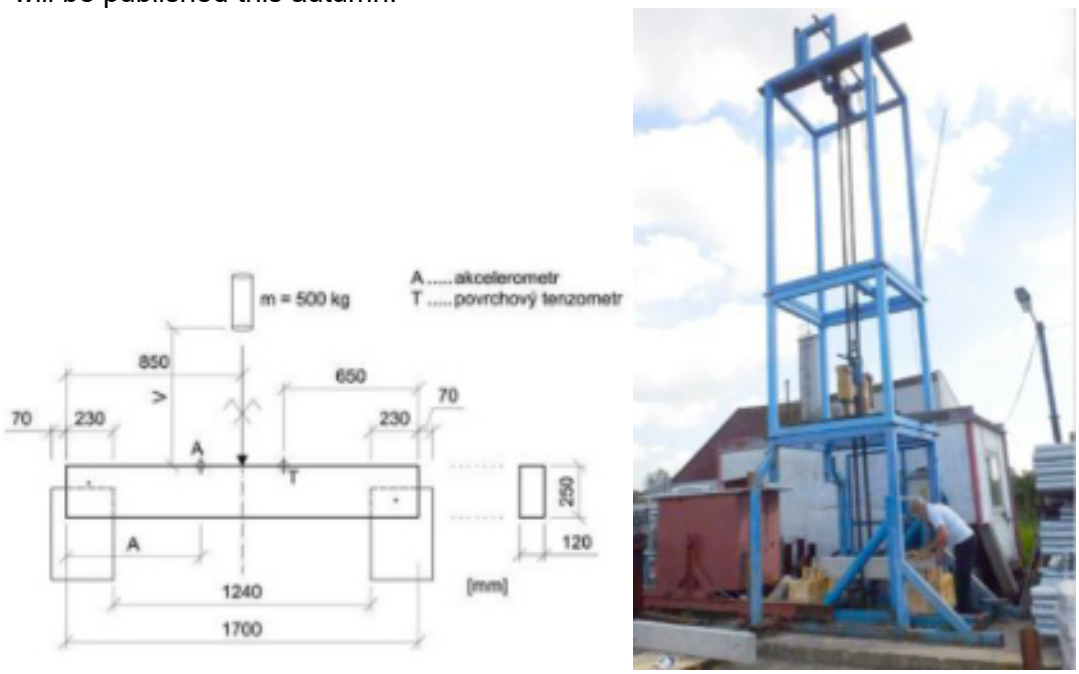

Fig. 49: Experimental determination of the viscous parameters of a reinforced concrete beam – diagram of the test configuration (left) and real configuration (right).

- As part of our cooperation with Ing. Pavel Busina's structural engineering office, tasks from the area of applied dynamics (the development and design of the superstructure of a mobile building and the calculation of the dynamic effects of a rotor) were

investigated. The results were published at the Czech conference Modelovani v mechanice (Modelling in Mechanics).

- In cooperation with COMET OBALY, s.r.o., the basic properties of three types of steel were examined, one of which was from rather old material without documentation. One of the outputs of the investigation was a recommendation for a suitable replacement for this historical steel. The details were published in a contribution at the Modelovani v mechanice conference.

8. Conclusion

The Center is in its fIfth year of full operation at Purkyňova 651/139, Brno. In 2019, it continued to be the Center of R&D solutions from previous years, including the international Shift2Rail project under the H2020 program. In total, 71 projects were solved in 2019, including cooperation projects between the application sphere and regional R&D Centers and 2 international projects (H2020). The Center continued its intensive cooperation with the application sphere, both in the area of contractual research and in the area of joint R&D projects. In 2019, the mobility of workers abroad and foreign workers to Center continued, contributing to the creation of new partnerships and new areas of international cooperation. The management of the Center considers the development of international cooperation and internationalization as one of the top priorities for the coming years.

In 2019, most of the monitoring indicators were met and, to a large extent, their annual planned values were overfulfilled.

Number of jobs (FTE) of R&D personnel:	**124**
Number of successful doctoral / master graduates:	**13/188**
Publications in impacted journals:	**26**
Publications in periodicals within the R&D methodology:	**66**
Applied research results (pilot plant, prototype, functional sample, etc.):	**12**
Number of contract research projects:	**236**
Number of R&D projects:	**71 + 2 international (Horizon 2020)**
Total commercial revenue:	**56,536 mil. Kč**
Of which contract research and other economic activities:	**29,836 mil. Kč**
Income from non–commercial activity:	**117,524 mil. Kč**
Total income:	**175,189 mil. Kč**

Generally, there has been a significant development of cooperation with the application sphere and the Center's turnover in contract research has been maintained. A positive phenomenon is that contract research is carried out in all areas of the research Center and individual projects are related to a number of customers. Thus, the Center's prosperity is not only tied to a few customers, allowing diversification of risks.

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