Annual Report
AdMaS Centre
2015

AdMaS
ADVANCED MATERIALS, STRUCTURES AND TECHNOLOGIES

Foreword by the Dean

Dear colleagues,
You are now holding a summary of the results of the work of the AdMaS Centre for the year 2015, i.e. from the first year of operation at our new premises. It was a year of settling in, finalising the administrative side of things, and getting engaged in the everyday life of the faculty. This year, we managed to complete the equipment of the centre with several devices whose tender procedure had been delayed due to a lack of time. This mainly concerned the set of fire test furnaces, which has been a key item for the centre from the beginning. Our first year was successful, both in the field of science and from the administrative and contractual research perspectives. We still have four years of project sustainability ahead of us. The results from the first year show that the current sustainability indicators will be fulfilled without any problems. I would like to thank all of those taking part for everything.

It is becoming obvious that certain expectations upon which the strategy of the Centre was based in the period of the creation of the project are not being fulfilled. On the other hand, new areas are opening up for us. This is a natural phenomenon as more than eight years have elapsed since the first plans were drawn up for the project and there have been significant shifts in the market. The management of the AdMaS Centre has thus updated the operational strategy of the Centre. This modern centre has provided our faculty with one of the best-equipped scientific and technical facilities in Europe. It is up to us how we will make use of the technological advantage we now have over other faculties.

Thank you once again for all the work you have done up to now. I believe that 2015 was just the beginning of a long-lasting and successful journey for the AdMaS Centre and its staff.

Prof. Ing. Rostislav Drochytka, CSc., MBA.
Dean

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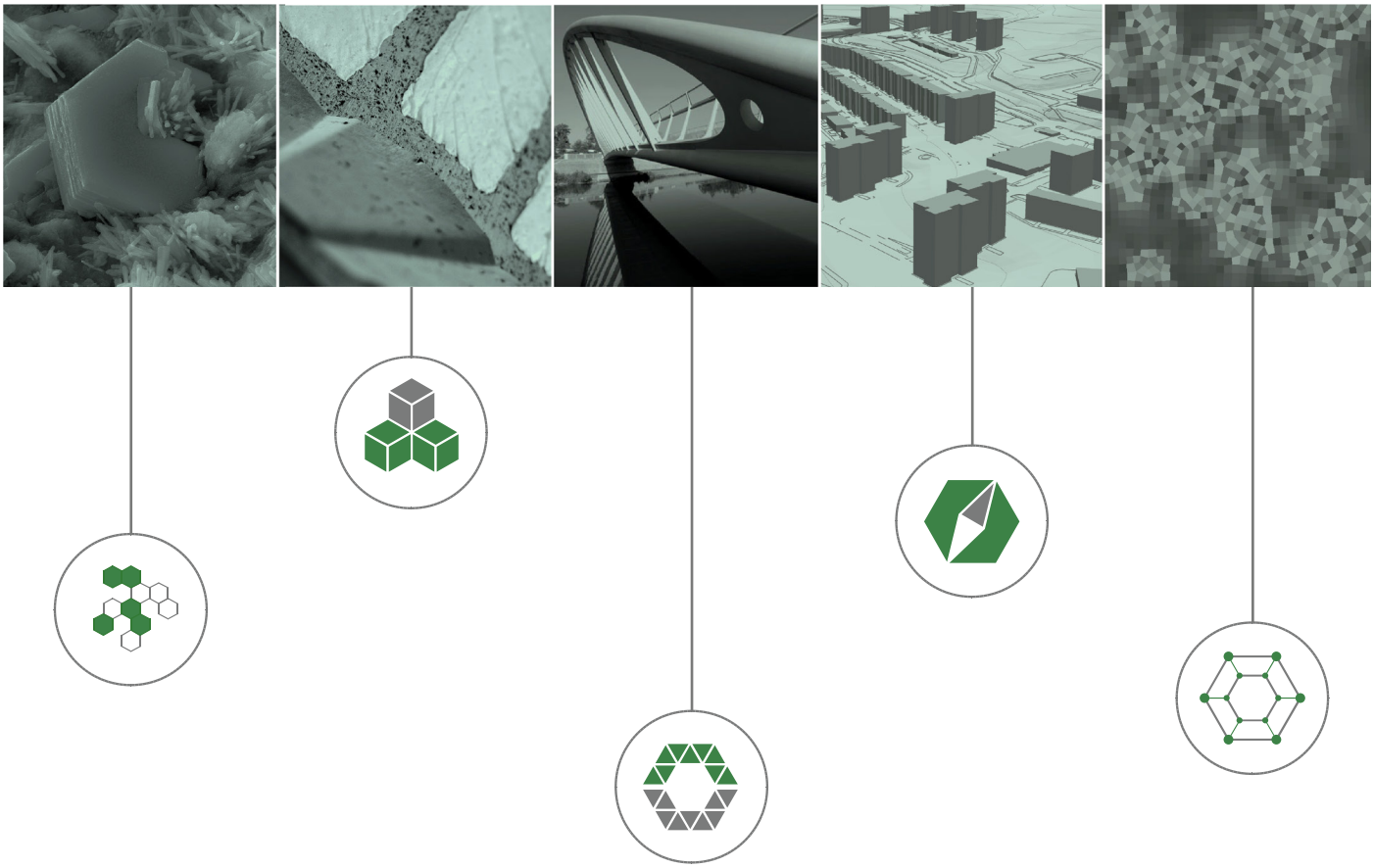


1. Organizational structure

Headquarters

Head of Centre	Ing. JUDr. Zdeněk Dufek, Ph.D.
Scientific Director of the Centre	Prof. Ing. Drahomír Novák, DrSc.
Deputy Director, Financial Manager	Ing. Zdeněk Krejza, Ph.D.
Deputy Director of the AdMaS UP project	Assoc. Prof. Mgr. Tomáš Apeltauer, Ph.D.
Administrative Manager	Ing. Jiří Zach, Ph.D.
Lawyer	JUDr. Sylva Pochopová
Facility Manager	Ing. Michaela Ulbrychová
Coordinator of International Projects	Mgr. Irena Šifaldová
Business Manager	Ing. Oliver Pospíšil
Secretariat	Zlatuše Dokoupilová

Research Programme RP1: Development of Advanced Building Materials

Head of Programme	Prof. Ing. Rostislav Drochytka CSc., MBA

Technology of Building Materials Research Group

Head of Research Group	Prof. Ing. Rudolf Hela, CSc.

Microstructure of Building Materials Research Group

Head of Research Group	Assoc. Prof. Ing. Jiří Bydžovský, CSc..

Research Programme RP2: Development of Advanced Structures and Technologies

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

Constructions and Traffic Structures Research Group

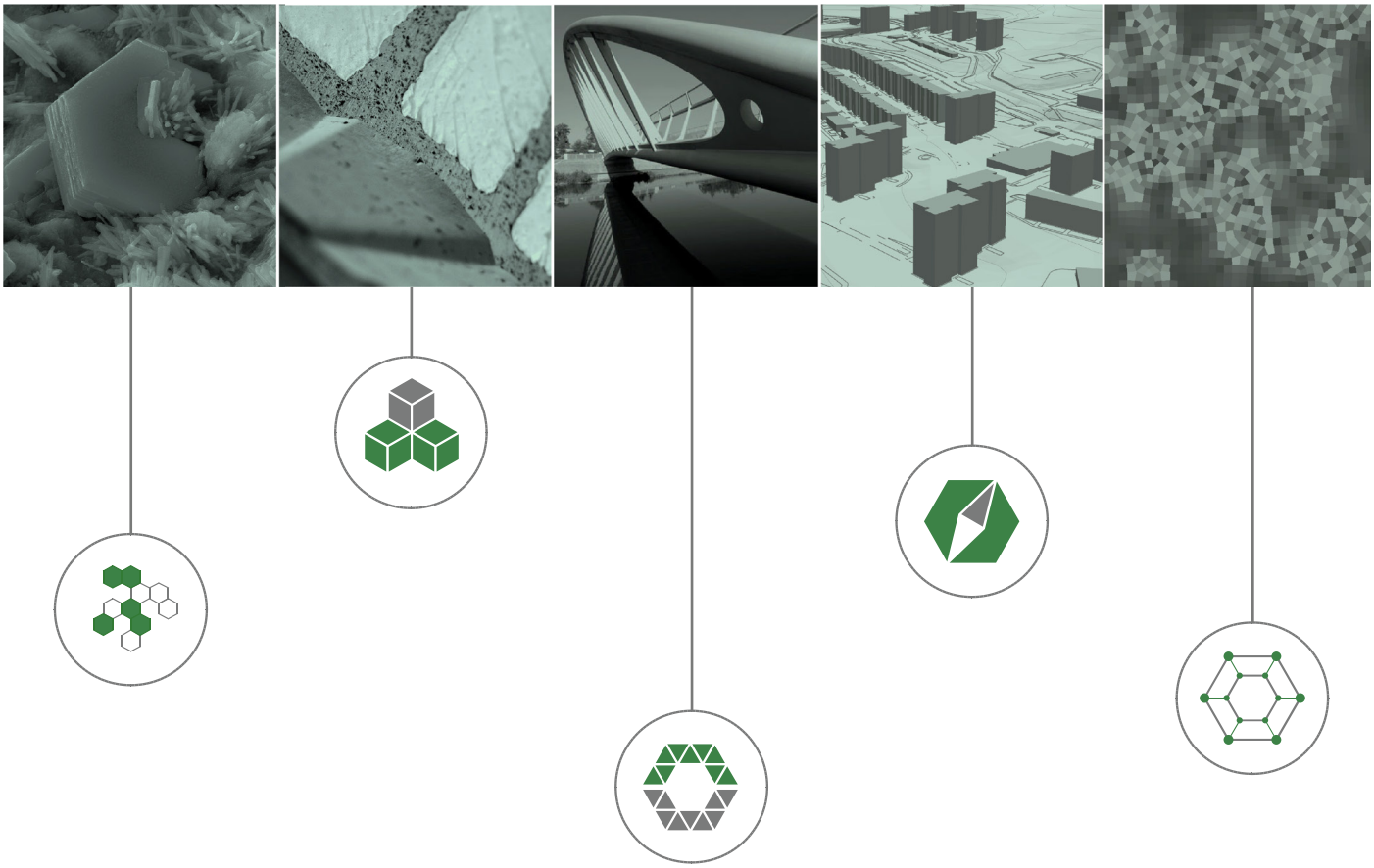
Head of Research Group	Assoc. Prof. Ing. Pavel Schmid, Ph.D.

EGAR Research Group

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

Mathematical Modelling Research Group

Head of Research Group	Prof. Ing. Drahomír Novák, DrSc.



2. Activities in the area of Centre management and control

At the end of February 2015, a final Monitoring Report was produced which was approved by the Regulatory Authority in December 2015. In the first half of 2015, an international evaluation of the AdMaS Centre took place. Immediately after the evaluation was complete, the centre began to implement the recommendations of the evaluators (e.g. the organization introduced "horizontal integration" – meetings between R&D staff and their colleagues from other research groups and working/scientific positions. The Centre also participated in promotional events, e.g. the Night of Scientists, Majáles, etc.). Another reaction by the AdMaS Centre to the evaluation involved the creation in 2015 of a new strategy for the institution. This focuses on the key areas of the Centre's activities and the development and support of the Centre's HR policy, and also on other critical areas from the perspective of the long-term growth and sustainability of the centre.

In addition, two social events were held for Centre employees and their research staff connected with a tour of the AdMaS Centre premises.

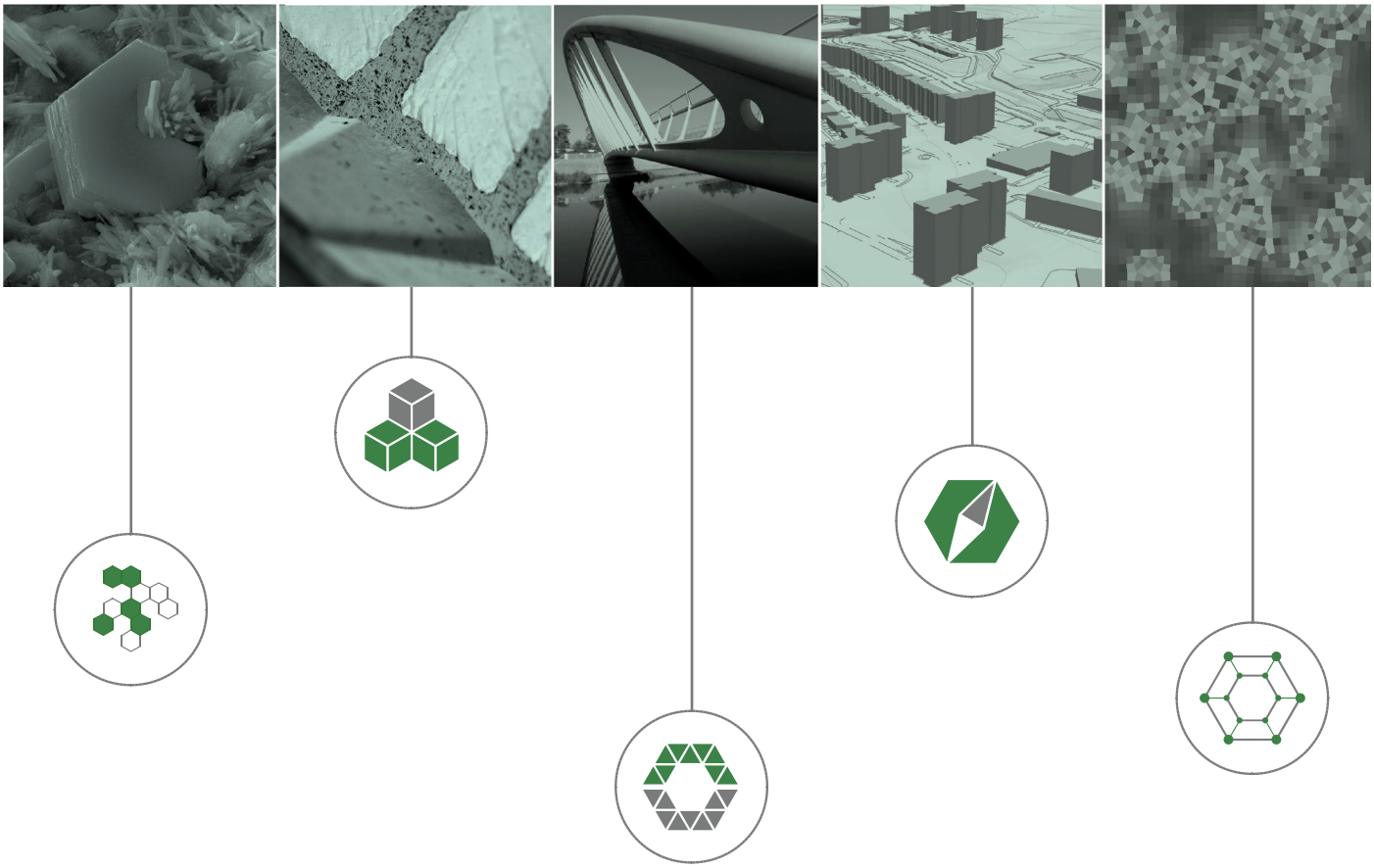
In accordance with the TA of the project, the management of the centre actively implemented the defined principles of its human resources policy. These mainly included the regular evaluation of R&D workers, personal and motivational interviews with Centre employees, and support from the Centre management for new projects and mobility (a Centre employee has been newly appointed for these activities – Mgr. Šifaldová, and active cooperation with the office for the South Moravian Region in Brussels took place with the aim of involving the centre in foreign R&D projects within the framework of H2020). Furthermore, the Centre management held regular monthly meetings (which included the representatives of individual research programmes and research groups).

As far as mobility is concerned, employees (in all R&D categories) engaged in research-related visits to foreign countries, and foreign research workers took up research stays at the AdMaS Centre. In addition, seminars and training sessions took place for employees of institutions engaged in the application of research results.

Active cooperation also took place with institutions engaged in the application of research, both in the area of contract research (the volume of contract research for 2015 /see MI 11120/ was 39 708 thousand CZK), and in the area of applied R&D projects (the volume of financial means within the framework of the Centre's R&D projects (apart from institutional support and the AdMaS UP Centre sustainability project) was /see MI 0603/ 56 113 thousand CZK).

A newsletter was published regularly by the Centre in 2015. It provides details on all the newsworthy happenings at the Centre and is used as an active tool for increasing the mutual awareness of Centre employees. The implementation of the "AdMaS – reinforcement of research capabilities" project took place from 1. 6. 2015 to 31. 12. 2015. The management of the centre administered a total of 8 research plans within the framework of this project.

2015 saw the presentation of the AdMaS Centre at the 3rd China International Technology Trade Fair in Shanghai, with the participation of JUDr. Ing. Zdeněk Dufek, Ph.D. Subsequently, communication with potential Chinese partners took place concerning R&D with the aim of involving the Centre in shared R&D projects.



3. Seminars and training

Seminars are also listed in the overview of Centre events within the MZ18 – Publicity section, as the possibilities offered by the AdMaS Centre have always been presented together with specialized topics.

- 29. 1. 2015 Presentation of the AdMaS Centre for the staff of the National Heritage Institute, Brno office, and heritage protection experts at the Methodological Centre of Modern Architecture at the National Heritage Institute Brno, Stiassni Villa. A memorandum was signed regarding cooperation between the AdMaS Centre and the National Heritage Institute. The seminar focused on construction-related technical research into historical buildings, the restoration of historical plasters, the structural remediation of buildings and the surveying of complex interior spaces using 3D scanning.

- 21. 4. 2015 Presentation meeting with management staff of the Technical and Test Institute for Construction at the AdMaS Centre. The seminar focused on new diagnostic methods and the specialised instruments with which the Centre is equipped.

- 14. 5. 2015 A workshop on Urban Rail-based Transport Infrastructure was conducted for the employees of the Brno Public Transport Company. The programme focused on the ČSN 28 0318 standard: Tramway track gauges and profiles for vehicles operated on tram lines, issues concerning continuous welded rails in tramway track structures, the interaction between wheel and rail on tramway tracks, and the structure of tramway track bed and ballast with regard to the lowering of noise and vibration.

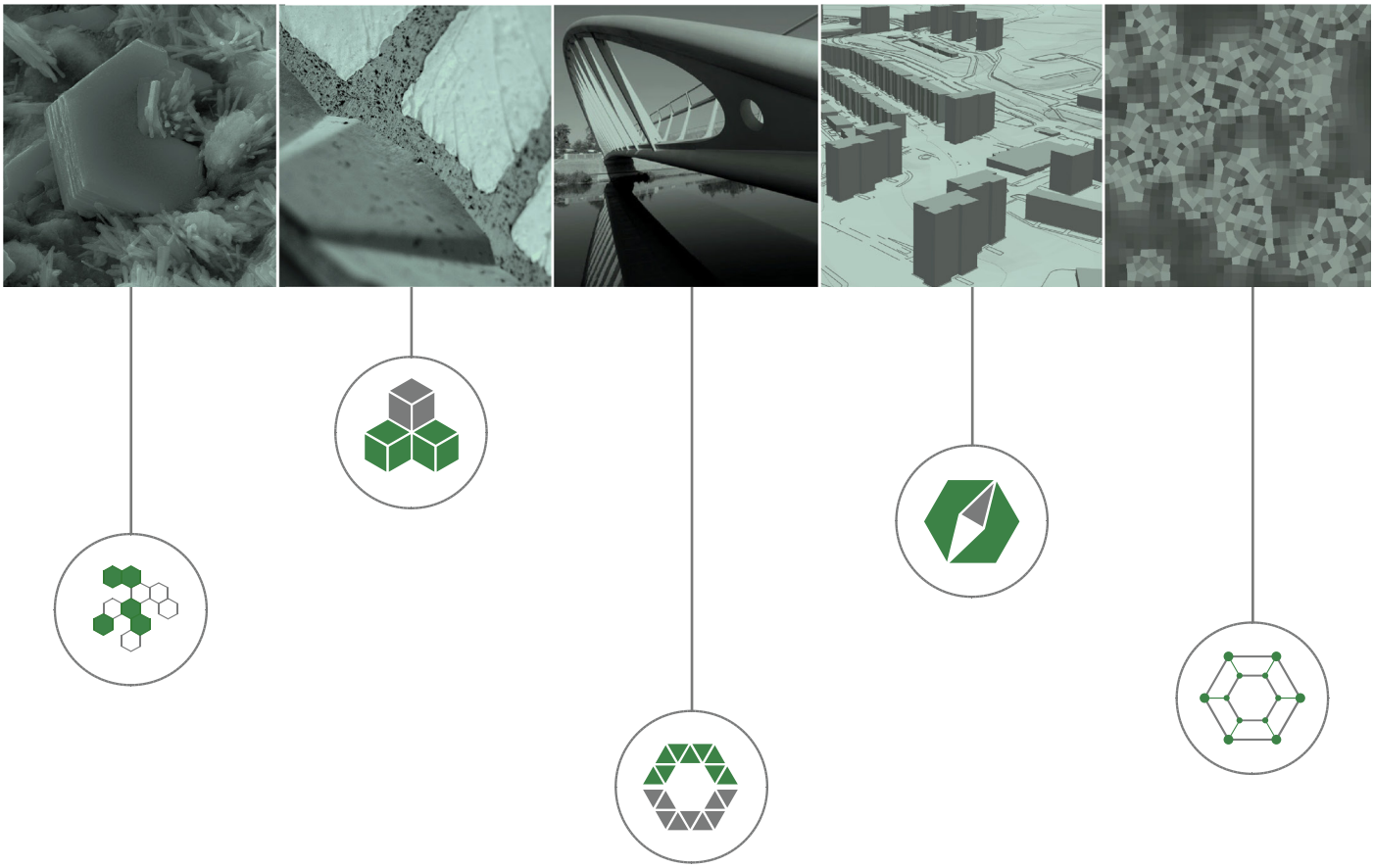
- 15. 5. 2015 Presentation meeting with the staff of the Road Management and Maintenance, South Moravian Region organisation at the AdMaS Centre. The seminar focused on new diagnostic methods in road transport engineering and the identification of the needs of regional road management.

- 27. 5. 2015 Meeting of the Investment Committee of the Council of the South Moravian Region at the AdMaS Centre. The main topic was issues concerning the evaluation of public tender bids, and the use of structure life cycle cost parameters under competitive conditions.

- 28. 5. 2015 Presentation meeting with technical management staff employed at SKANSKA, a.s. The seminar focused on the use of simple diagnostic methods which can be used by construction managers at construction sites, as well as the application of the Centre's research in building production.

- 11. 6. 2015 Presentation meeting at the AdMaS Centre with representatives of the National Construction Centre. The seminar focused on the quality of consultation services and the energy management of buildings.

- 18. 6. 2015 Meeting of Brno City Council's SMART City Committee at the AdMaS Centre. The seminar focused mainly on the area of energy savings in public buildings, the use of non-incinerable communal waste residues, innovative solutions for parking, and the alternative transport solution offered by utilisation of the Bike Sharing service.



4. Mobility of research workers and cooperation with foreign countries

In 2015, mobility and the exchange of staff between the AdMaS Centre and foreign scientific institutions took place.

A total of 9 Ph.D. staff (Bílek, Jedličková, Slowik, Rypl, Sobek, Novák, Larišová, Němcová and Velehrach) underwent short-term research stays abroad at the following foreign universities and research institutions: Hochschule für Life Sciences FHNW, Switzerland; BOKU Wien, Austria; University of Oviedo, Gijon, Spain; Shanghai Research Institute of Building Sciences, 75 WanPing Road (South), Shanghai; Belgrade University – Department of Forestry Science, Kneza Višeslava 1, 11030 Belgrade; Technische Universität Dresden; Newcastle University). The aim of the foreign research stays at Universität Dresden and Newcastle University was to study and expand existing knowledge in the area of the origin, development and mechanics of slip waves in small-diameter turns. This issue was examined during the stay for tram lines and mainly railway tracks (the effects of vehicles from various European states). The research stay included the viewing of selected sections of tram lines in the Dresden public transport company network with demonstrations of wavelike deformations, as well as excursions to Göltzschtalbrücke and Elstertalbrücke.

Furthermore, Ing. Tomáš Koudelka took part in an overseas specialized research stay with MATtest Ltd. in Great Britain. His job mainly involved the execution of tests at the firm's road laboratory in the town of Maidstone, as well as helping with the management of a branch of this laboratory. During the research stay, the student also took part in a research project focused on asphalt mixes with a high content of R-material, which is also being dealt with in the CESTI project carried out under the auspices of the AdMaS Research Centre. This project took place in cooperation with Honeywell's Belgian branch.

Furthermore, one student from the Doctoral study programme underwent a long-term research stay at the University of Edinburgh, at the BRE Centre for Fire Safety Engineering, within the framework of the Freemovers programme. During her stay she took part in the testing of various materials. The main programme of the stay involved cooperation with local Doctoral students, testing the fire resistance of various materials, and specialized discussions concerning the fire resistance of concrete exposed to the effects of high temperatures.

9 short-term research stays took place at the Junior Researcher level (staff: Šimonová, Podroužek, Veselý, Dvořák, Vajkay, Krmíček, Sobotková, Bečkovský and Vajkay) at foreign universities and research institutions (Deutsches GeoForschungsZentrum Potsdam Universität Potsdam / The stay focused both on the laboratory study of geomaterials and on the development of closer cooperation between Deutsches GeoForschungsZentrum Potsdam, Universität Potsdam and FCE BUT's AdMaS Centre in Brno/, TU Wien, University of Split, University of Oviedo, CIITEC IPN Centro de Investigación e Innovación Tecnológica Mexico / The task was an experiment concerning high-speed milling in a ZOZ-type Attritor mill, Oulu University of Applied Sciences, Belgrade University).

A total of 12 short-term mobility trips took place at the Senior Researcher level (staff: Hroudová, Novák, Vořechovský, Mohelníková, Bečkovský, Zach and Dumbrovský) at foreign universities and research institutions (TU Wien, Shanghai Research Institute of Building Sciences, University of Catalunya, Universidad de Oviedo, The University of Bath, Oulu University of Applied Sciences, BIOFORSK Norway, Belgrade University).

In 2015, a total of 11 short-term research stays involving specialized and scientific workers from foreign universities took place at the AdMaS Centre (institutions: TU Wien and the Technical University of Catalonia).

A Doctoral student who was involved in the AdMaS-UP project took part in a week-long research stay at the University of Ljubljana, Faculty of Civil and Geodetic Engineering, Chair of Metal Structures, Slovenia, where selected specialized questions were discussed along with the options for cooperation within the framework of currently implemented research projects, particularly in the area of loading tests.

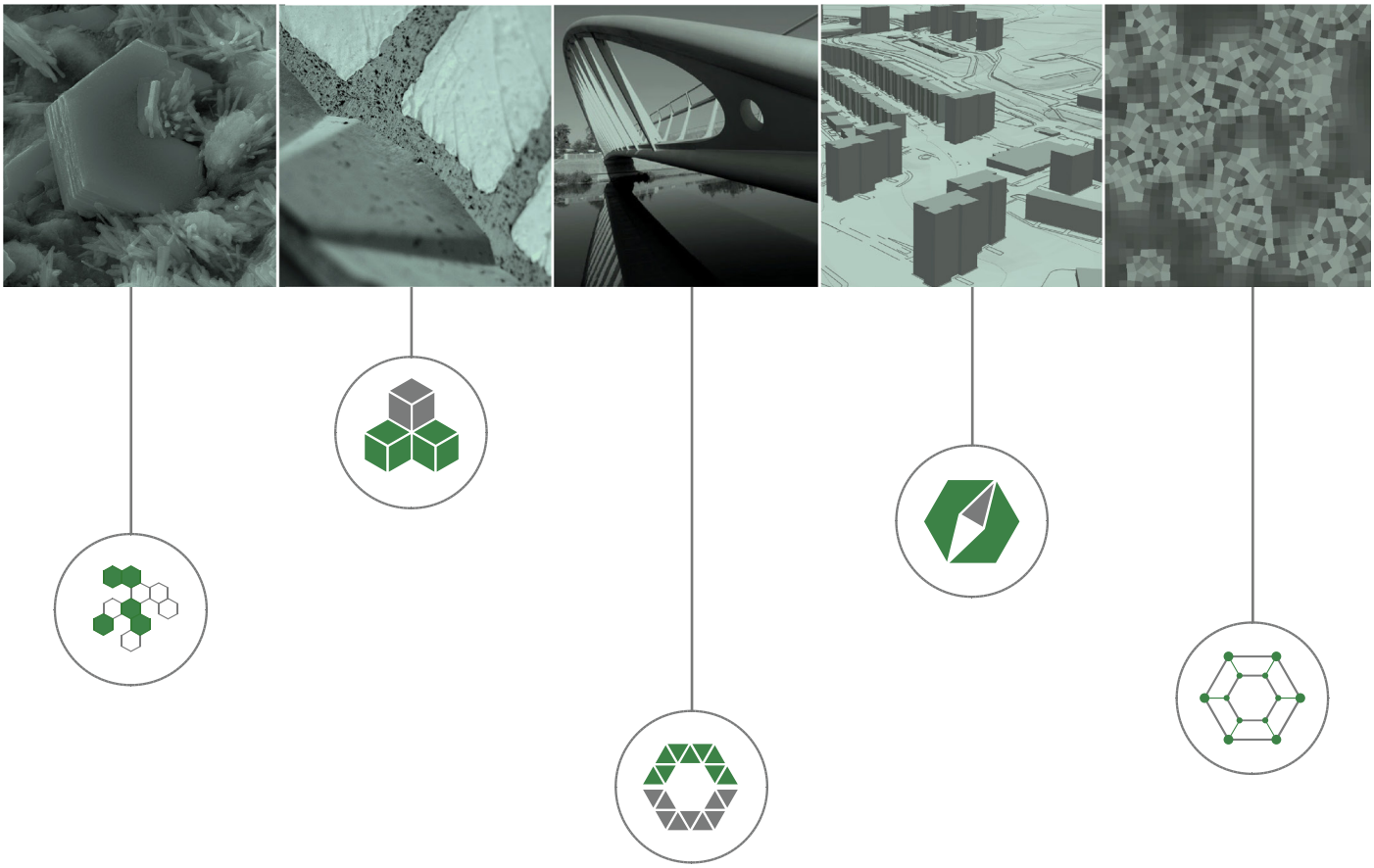
Dr. Johannes Kimbauer's stay at the AdMaS Centre can be named as a specific case. Dr. Kimbauer was involved in the development of cement-based silicate composites in cooperation with VP1 staff. He was specifically engaged in the measurement of particle sizes using our Mastersizer 2000 instrument.

A further example of mobility was the research stay of the Mathematical Modelling Research Programme Scholar - Dipl. Ing. Andreas Schneemayer (length of stay 3 months). The person responsible for the fulfilment of the scholar's research task was Prof. Ing. Zbyněk Keršner, CSc. The subject of the research stay from a specialized point of view was the evaluation of fracture tests conducted as part of an extensive experimental campaign of Wedge Splitting Tests and consultations regarding the investigated issues. Special attention was paid to the analysis of the outputs of acoustic emission (AE) testing, which is used for the determination of the fracture process zone during wedge splitting tests or the three-point bending of bodies with a stress concentrator.

As regards research stays of external staff involved in the application of research results, short-term stays occurred in connection with common collaborative R&D projects (see MI 0603) and also with training and seminars which took place at the AdMaS Centre.

In 2015, a Memorandum was signed concerning mutual cooperation with Buch International University of Sarajevo and a shared project was created, ERASMUS+ KA01, which was selected for support. It is expected that the first mutual mobility trips will occur in 2016, including the hosting of staff from Buch International University on long-term research stays at the AdMaS Centre.

H2020 research projects have also been submitted in which the AdMaS Centre is involved in the position of a coordinator as well as a partner. So far, none of the submitted projects have been selected for support.



5. Fulfilment of milestones

In 2015, all binding milestones of the project were fulfilled.

Milestones related to the implementation of the project and the operation of the Centre:

- launch of full operations 1Q/2015

This milestone was achieved with the launch of full operations at the Centre's premises from 1. 1. 2015, when the Centre started to function with a complete set of acquired instruments and equipment (the delivery of the last instrument took place on 31. 12. 2014).

Research outputs of the project:

- publication in important international as well as domestic journals: at least 10x by 4Q/2015,
- publication at important international as well as domestic conferences: at least 15x by 4Q/2015,
- certified methodologies: at least 4x by 4Q/2015,
- submission of at least one utility model application by 4Q/2015.

By 2015, a total of 327 articles had been published either in journals or as contributions presented at domestic and foreign conferences. Out of these, a total of 69 were in high-impact factor publications. As far as publications at conferences are concerned, more than 70 contributions were published just in 2015 (see MI 110 502 – Other publications, and also many contributions were published at conferences which are not listed in the Information Register of R&D Results).

As far as certified methodologies are concerned, the following methodologies were certified by 2015:

- DAŠEK, O.; HÝZL, P.; COUFALÍK, P.; VARAUS, M.; STEHLÍK, D.; ŠPAČEK, P.; HEGR, Z.; STOKLÁSEK, S.; MATOUŠEK, D.; SVOBODA, P.: 3xRTFOT; Methodology for the evaluation of road asphalts from the aspect of their vulnerability to thermo-oxidative aging. (certified methodology), 2015

- DAŠEK, O.; HÝZL, P.; COUFALÍK, P.; VARAUS, M.; STEHLÍK, D.; ŠPAČEK, P.; HEGR, Z.; STOKLÁSEK, S.; MATOUŠEK, D.; SVOBODA, P.: BSA; Methodology describing the laboratory aging of asphalt mixtures. (certified methodology), 2015

- ZDRAŽIL, K.; KOTAČKOVÁ, A.; FIALA, R.; BOŠTÍK, Methodology for testing the quality and level of improvement of base soil with gravel pillars (certified methodology), 2015.

Other outputs were created outside the framework of the plan of identical / equivalent research values according to the government methodology of the Section for Science, Research and Innovation, see MI 110504, where the aggregate value of this monitoring indicator (MI) was 76 by 31.12.2015 (the required binding value for this MI is 55).

As far as utility models are concerned, a total of 4 utility models were listed in MI 110504 just in 2015. The milestone was thus fulfilled.

With regard to individual research projects, apart from the milestones stated above, the following milestones existed for the period in question:

- 1Q/2015 – Attainment of the full number (headcount) of scientific staff in the Development of Advanced Building Materials programme

This milestone was also fulfilled beyond that which was stipulated in all cases. The number of workers in both research programmes was increased above the originally planned state according to the TA from the period when the Decision was issued.

- Organization of at least one workshop focused on new knowledge regarding the behaviour of structures/buildings, technologies and materials in the previous year of project implementation and every year during the sustainability period

- Organization of at least one workshop focused on new procedures for the design and assessment of structures/buildings or technologies in the previous year of project implementation, and every year during the sustainability period

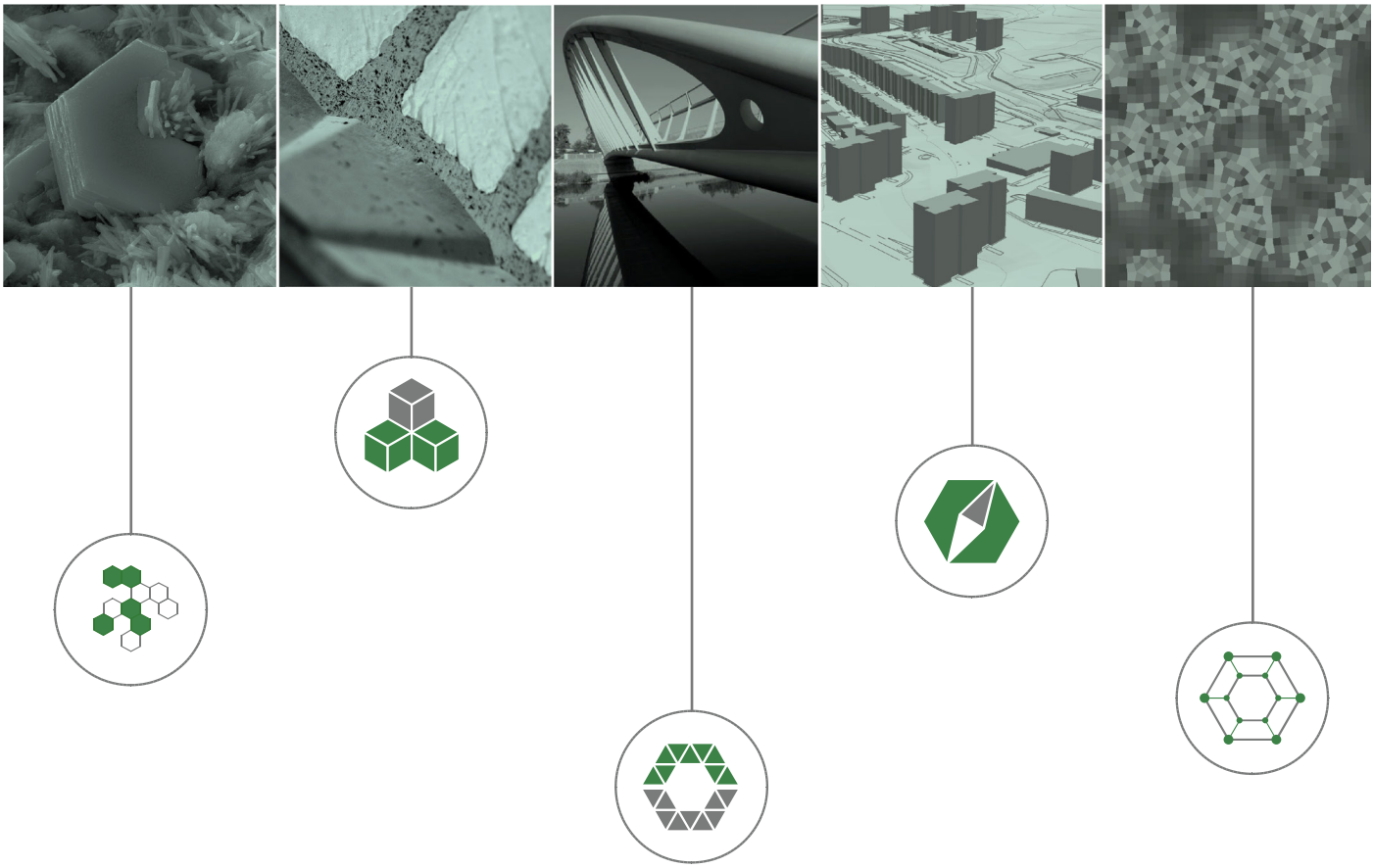
In 2015, a total of 8 workshops and seminars were organized that focused on new knowledge concerning the behaviour of structures/buildings, technologies and materials, and on the area of new approaches to the design and assessment of structures/buildings or technologies – see part 2 of this document above.

In the area of milestones connected with human resources policy, the following milestones were relevant for 2015:

- Research stays of external staff at the Centre: Duration 1-2 weeks, with at least 4 mobility trips by staff at least 4 per year, since 3Q/2014

Research stays were arranged for external staff within the framework of applied research projects (Ministry of Industry and Trade of the Czech Republic and TACR projects) where the staff of companies involved in the application of research results took part in research activities at the AdMaS Centre facility. It is expected that external staff will undergo long-term research stays at the Centre in 2016.

- • Mobility of Centre employees to companies engaged in the application of research results: duration 1-4 weeks, for at least 50% of those in the position of Ph.D. student staff members during their studies.



6. Research activities at the Centre

6.1. The RP1 Research Programme

Fulfilment of the aims of the RP1 Research Programme: Development of Advanced Building Materials was completely in accordance with the specialized focus and expected aims described in the TA for the period of the year 2015.

6.1.1. Research activities of the RP1 Research Programme

Research staff members were involved in analysing the internal structure of concretes exposed to the influence of high temperatures with the use of X-ray tomography, and the microstructure of light and decorative plasters with altered compositions. They conducted research into the creation of the mineral tobermorite for various porous concrete mix compositions, including the influence of autoclaving mode, and the development of the microstructure of ash over time with regard to various types of ash.

As a part of research into the microstructure of building materials, the question of the influence of milling modes on the structure of plaster was examined, as well as, e.g. the structural development of artificial aggregates fabricated from various types of ash. In the area of ceramics and masonry elements, research staff focused on the development of masonry elements with a high resistance to humidity, and also (for example) on the hydrophobization of masonry and the improvement of the frost resistance of ceramic elements rated according to pore distribution, including the discovery of raw materials suitable for their production.

One of the most significant areas of the research activities of the RP1 research programme has long been concrete technology. In this area, attention was mainly focused on activities such as temperature regulation in high-strength concretes, the study of the behaviour of concrete and cement composites exposed to high temperatures (especially shotcrete for extreme temperatures) and, last but not least, light concretes and elements such as pre-fabricated ceiling and wall boards. As part of the drive to increase utility properties and lower costs, the question of whether zeolite can be used to partially replace cement in aerated concretes was also investigated. Great attention was also paid to fluidized bed combustion (FBC) and high-temperature ashes with regard to the development of a new hydraulic binder based on FBC, the use of FBC as an additive in Portland cement, and the maximum use of ash as a replacement for cement in high-strength floor screeds (see Fig. 1).

The researchers involved in the physical part of the programme focused on the study of the correlation between acoustic emission parameters and fracture characteristics obtained from three-point bending, the evaluation of the static modulus of elasticity with regard to its dependence on the compressive strength of concrete, and the comparison of ultrasound impulse and resonance measurements of the dynamic Young´s elastic modulus.

In the area of insulation materials, research workers examined the options for the use of natural and textile fibre for insulation materials, and their behaviour under various types of thermal and humidity stress. The development of masonry blocks with thermal insulation or thermal insulation plasters with natural fibres is also worth mentioning. Another important area of research is that of patching materials, which were investigated in connection with the replacement of silicate binder especially for materials for extreme temperature conditions, and regarding the influence of high temperatures or aggressive environments on the properties and microstructure of these materials. One special area was that of materials and technologies for the remediation of rockfill dams. Suitable recipes and the technology itself were verified on examples of remediation work in cooperation with a firm actively engaged in the field (see Fig. 2).

The activities of individual RP1 researchers are continuously being published in important world periodicals and at conferences and workshops. Not only is the latest knowledge concerning R&D presented, but also the Centre as a whole. New contacts for future cooperation in the area of R&D and individual orders are being established. The achieved results are also being registered in the form of functional samples, verified technologies, etc. It is not only important research workers in senior researcher positions that are significantly involved in the activities of the research groups, but also (and indeed mainly) young researchers in junior researcher positions who also cooperate closely with Bachelor´s, Master´s and Doctoral students and pass on their experience to them.

As far as the fulfilment of tasks according to the TA is concerned, the following examples can also be mentioned:

- In 2015, in the area "Proposal of efficient uses of materials in building structures with regard to their lifespan and economic application," a registration was submitted for a utility model called Surface layers of brick buildings utilizing ground brick (16. 2. 2016 – registered in the Utility model register under the number 29162). In 2015, over 10 functional samples of new progressive materials were registered, e.g. protective coatings, adhesive primers, floor screeds, remediation materials for high temperatures and injection materials. During the development of new materials, emphasis was mainly placed on increasing the lifespan of building materials and structures while ensuring the competitiveness of the new materials. The resistance and high lifespan of the new materials was tested both at high temperatures and in various types of aggressive environments. Competitiveness is ensured via the efficient use of raw materials, including those of the secondary type.

- In the area "Development of new non-destructive methods that can be employed in the quality control of materials as they exit manufacturers' premises or after their implementation in structures", mainly optimized X-ray tomography, georadar and acoustic emission methods were verified. In the case of X-ray tomography, the option of carrying out the non-destructive analysis of the structure of a product or part of a built structure can be used with advantage, as can the technique's ability to find where weak points often occur, as they can be a source of defects. The georadar was mainly useful when checking the effectiveness of the remediation ofa backfill dam and assessing the state of concrete structures. The acoustic emission method can monitor the state of a newly implemented structure efficiently and identify locations where possible defects could occur in a timely manner.

- In the area "Creation of legislative documents (methodology, technical standards) for the production and testing of building materials", a Czech ČSN class 73 technical standard named "Structural inspections of reinforced concrete cooling towers in industrial facilities" was created. Also, several verified technologies were designed and methods introduced for working procedures to be used when conducting experiments and checking the quality of fabricated products not only in a laboratory environment but also in the operating conditions of a production plant.

- Within the framework of basic research, primarily Czech Science Foundation projects were implemented, such as:
  - 15-07657S Study of the kinetics of events taking place in a composite system at extreme temperatures and during exposure to an aggressive environment
  - 15-08755S Monitoring the influence of burning technique on the properties of lime
  - 15-23219S Study of nanoparticle dispersion methods, and the determination of conditions limiting their repeated clustering for application in cement composites
  - 14-31248P Study of the influence of built-in hazardous waste on the properties of cement matrix
  - 14-25504S Research into the behaviour of composites based on inorganic matrices in extreme conditions
  - 14-31282P Theoretical and experimental analysis of the influence of humidity load on the behaviour of thermal insulation and remediation materials
  - 14-32942S The influence of FBC ash on the thermodynamic stability of hydraulic binders
  - 13-21791S Study of heat and humidity transport within the structure of natural fibre-based insulation materials
  - 13-23051S Anorthite porcelain shard based on alumina cement

6.1.2. Usage of laboratory instruments in the RP1 Research Programme

While pursuing the aims of the project, efficient use was made of our new laboratory instruments, such as the XRD device with Rietveld refinement, high-temperature chamber and SAXS, the REM with environmental probe and 3D depiction, and the XRF fluorescence spectrometer.

- The REM was used for:
  - the identification of phases occurring during the hydration of cement with the presence of amorphous forms of silicon dioxide (GA 14-04522S),
  - the analysis of the structure of produced ash shards, focusing on the development of melt and on the elemental composition of the created products (GA 13-30753P),
  - observing the microstructure and phase composition of the products of the reaction of ground brick with lime and cement binder (MPO FR-TI4/014),
  - observing changes in the microstructure of samples of fine-grained concretes exposed to sulphuric acid (GA 13-22899P).

- The XRD was used not only for the above-mentioned Czech Science Foundation projects but also for research in the following areas:
  - termodynamické stability AFT fází na bázi ettringitu (diplomová práce Bc. Jana Mokrá),
  - the thermodynamic stability of ettringite-based AFT phases (diploma thesis - Bc. Jana Mokrá),
  - the thermodynamic stability of thaumasite-based AFT phases (diploma thesis - Bc. Miroslav Skřeček),
  - the amortization of materials processed via milling (diploma thesis - Bc. Jakub Dočkal),
  - the influence of raw material and limestone burning technique on the properties of lime (diploma thesis - Bc. Karel Urban),
  - the characterization and comparison of the microstructure of burnt clinkers containing heavy metals and cement pastes with fixed heavy metals. The composition of the individual morphologically different components in the examined samples was determined by EDX probe (diploma thesis - Bc. Kateřina Kašpárková),
  - the analysis of the level of crystallization of crystalline admixture for addition to concrete using the REM and EDX probe
  - the analysis of the microstructure of concrete with added diatomaceous earth studied using the REM and EDX probe,
  - the evaluation of the structure of autoclaved porous concrete from the perspective of quality and the level of development of tobermoritic phase with various SiO2:CaO ratios, autoclaving durations, and proportions of aluminium, sulphates, etc. (diploma thesis - Bc. Ján Fleischhacker),
  - the structural development of cinder stabilized mixtures (contractual research for SAKO Brno, a.s.),

- XRF - In 2015, the XRF was mainly used to determine the sulphate content in samples exposed to sulphate corrosion during the investigation of Czech Science Foundation project 13-22899P: Study and modelling of the sulphate corrosion of concrete. A spectrometer was also used for the determination of the composition of input raw materials used for the production of Bachelor´s, diploma and dissertation theses (cement, limestone, brick dust).

- QUV and Q-SUN instruments for the determination of degradation due to the influence of artificial solar radiation were used to test (among other things) the resistance of newly developed surface treatments for cement bonded particleboards, which is being investigated within the framework of project TH01020282. This project deals with structured surface finishes for cement bonded particleboards with extreme resistance and high lifespan. With the help of the devices mentioned above, it was possible to observe the influence of a combination of increased temperatures, UV radiation and condensed humidity on changes to the properties of surface finishes applied directly to cement bonded particleboards. The listed conditions were alternated cyclically. The obverse surface was stressed with the aid of the QUV, and the exposure of all surfaces took place in the Q-SUN. The focus was on the edges, which are particularly problematic. During the course of exposure, a CMD-600D spectrophotometer was used to observe changes in colour parameters.

- Testing chambers and equipment – with regard to order HS 125N1035/12514/15, a Köhler Automobiltechnik GmBh (Lippstadt, Germany) corrosion cabinet was used to evaluate the durability of steels used as material in the load-bearing structures of very high voltage distribution networks. Specifically, steels with FeZn surface treatment and low-alloy steels with higher resistance to atmospheric effects (Atmofix, Corten) were tested. As a standard test, the NSS test (a test with neutral salt mist) was carried out according to the ČSN EN ISO 9227 Standard in a chamber with controlled atmosphere. Simultaneously, a test using a combination of hydrochloric and sulphuric acid salt solutions with the concentrations 0.5% NaCl and 0.35% (NH4)SO4 was also applied. After the tests were complete, visual and microscopic analyses of the surfaces of the tested materials were carried out. A TESCAN electron microscope was used for these purposes. The surface of the sample was also evaluated metallographically: the steel samples were cut after the end of exposure and then monitored in the field of vision and recorded digitally via a LEICA DM4000 light microscope and a LEICA camera.

- In 2015, the RP1 mobile laboratory was used for a total of 95 trips for the purpose of taking measurements and samples, which is approximately 38% of all the working days in the year. These were mainly trips to production plants and specific projects such as:
  - The drilling of products for street inlets, cisterns, water shafts, shaft bottoms, etc. Individual tests were subsequently performed on the products to assess such characteristics as compressive strength, resistance against chemical de-icing agents, etc., which subsequently led to the optimization of recipes,
  - the performance of basic analyses on high-temperature ash and slag such as sieve analysis, infusion pH, bulk density, density, etc. Simultaneously, samples were taken for further laboratory activities,
  - the testing of fresh concrete – slump test and air content – and the production of test specimens,
  - the sieve analysis of aggregate, determination of the shape index and sand equivalent, etc.,
  - the testing of fresh floor screed, with the execution of tear tests to determine the adhesion of matured screed samples and adhesive primer-screed layering, and also the production of test specimens for laboratory tests and analyses,
  - the testing of the parameters of surface finishes of cement bonded particleboard. A study was conducted at a manufacturer's premises regarding the properties of a surface finish exposed to real adverse conditions. Specifically, the adhesion of the surface finish to the base was assessed using an adhesion tester, the change of colour hue tested using a spectrophotometer, and adhesion evaluated using the grid method.
  - the majority of the work was carried out within the framework of contractual research, and thus mainly fulfilled MI No. 111200 (Volume of contractual research). Part of the work was focused on applied research within Technology Agency of the Czech Republic and Ministry of Industry and Trade projects, mainly fulfilling indicators No. 110502 (Publication) and No. 110504 (Applied research results).

6.1.3. Contractual research of the RP1 Research Programme

Cooperation with partners in projects supported by the Ministry of Industry and Trade (MPO), the Technology Agency of the Czech Republic (TAČR) and Czech Science Foundation (GAČR), as well as partners in the execution of contractual research, was excellent, with the activities of the individual cooperating organisations complimenting one another effectively. This involved collaboration with producers of raw materials, manufacturers of materials and parts, organisations planning to apply research findings in the future, and other research organisations.

The following cases can be named specifically:

- cooperation with the company CIDEM Hranice, Cetris Division, during the execution of TAČR project TH01020282 – New structured surface finishes for cement bonded particleboards with extreme resistance and high lifespan. The producer of the new surface finishes is fully cooperating in their development and testing under operating conditions.

- cooperation with the companies BETOSAN s.r.o. and KOMFORT, a.s. during the investigation of TAČR project TA04010143 – Research into and development of a new system of silicate-based floors for extreme mechanical and chemical loading. Within the framework of this cooperation, the development activities of BETOSAN and BUT are connected with a representative of the area of industry where the findings could be applied - the company KOMFORT.

- cooperation with the company Hradecký Písek a.s. during the implementation of MPO project FR-TI4/335 – New advanced techniques for the remediation of rockfill dams. BUT's research and development activities were suitably supplemented by practical testing conducted by the future user of the techniques.

- cooperation with the company Lime Business Consulting s.r.o. in the investigation of GAČR grant project 15-08755S – A study of the influence of the preparation of samples on the resultant properties of inorganic binders. The know-how and many years of experience of the co-investigator are advantageously combined with the latest knowledge from the field of specialization of the investigator from BUT.

- cooperation with the company Redrock Construction s.r.o. in the execution of contractual research aimed at developing special adhesives for the gluing of basalt tiling elements.

Similarly, other examples of cooperation in the investigation of basic, applied and contractual research projects can be named, e.g. with the companies Dosting, s.r.o., SAKO Brno a.s., Pískovna Černovice, spol. s r.o., FATRA, a.s., INFRAM CZ, a.s., Pokorný, spol. s r.o., PREFA KOMPOZITY,a.s., Lias Vintířov, lehký stavební materiál k.s., CEMEX Czech Republic, s.r.o. and ČEZ Energetické produkty, s.r.o. Cooperation is also taking place with universities such as the Czech Technical University, Tomas Bata University in Zlín, the Institute of Geonics at the Czech Academy of Sciences, v. v. i., etc.

In 2015, cooperation began not only in the execution of basic and applied research projects but also within contractual research. The newly-started projects include:

- TAČR TH01020282 with the company CIDEM Hranice, a. s.
- TAČR TH01030054 with the company Fatra, a. s. and Tomas Bata University in Zlín
- GAČR 15-08755S with the company Lime Business Consulting s. r. o.
- GAČR GA15-23219S with the Institute of Geonics at the Czech Academy of Sciences, v. v. i.
- Karlovy Vary Region innovation voucher with the company Sedlecký kaolín, a. s. Božičany
- South Moravian Region innovation voucher with the company INFRAM a. s.

Within the framework of cooperation with the National Heritage Institute, a shared NAKI II project was submitted (and awarded in 2016) named: The analysis and presentation of the values of modern architecture of the 1960s and 1970s as part of the national and cultural identity of the Czech Republic. Investigation period 1. 3. 2016 to 31. 12. 2020.

Within the framework of contractual research, cooperation began with, e.g. the company SAKO Brno a.s. concerning research into the usability of cinders in building materials. Furthermore, cooperation commenced with Pískovna Černovice, spol. s r.o. concerning research into the uses of excavated sand. Two agreements to provide contractual research were entered into with the Czech Technical University. These involved the AdMaS Centre becoming the sub-supplier for the execution of a project focused on special fast-hardening cement composites. A joint AdMaS-CEITEC workplace was also created in the area of CT in 2015.

Fig. No. 1
Verification of a technique for the construction of floors suitable for high operating loads

Fig. No. 2
Verification of a rockfill dam remediation technique.

6.2. The RP2 Research Programme

6.2.1. Research activities of the Constructions and Traffic Structures Research Group

In 2015, while engaged in projects supported by the Technological Agency, cooperation took place with the Czech Technical University in Prague, and also with the companies Vladimír Fišer and IDEA RS. Issues investigated within the framework of TAČR projects contribute to the fulfilment of the aims of the NPU (AdMaS-UP) project. Furthermore, many contractual research projects were undertaken in which some of the most important foreign partners were NEDCON (Holland) and LINDAB (Luxembourg). As far as Czech partners are concerned, these were EGP INVEST, spol. s r.o., Pokorný, spol. s r.o. and Fosfa a.s., the Directorate of Roads and Motorways, the Technical and Test Institute for Construction Prague, and the State Office for Nuclear Safety.

Within the framework of the Competence Centre project of the Technological Agency of the Czech Republic (TAČR, project No. TE01020168), cooperation has occurred with industrial partners and rail infrastructure administrators. One of the most important is DT – Výhybkárna a strojírna a.s. Cooperation has focused mainly on the development of high-speed points, a process which over the next few years should lead to the creation of the first functional sample of these points, which will be inserted into a track owned by the Railway Infrastructure Administration (SŽDS) for testing. One of our Doctoral students, Ing. Lukáš Raif, has become an employee at the development department of the above-named company.Cooperation has been established with Universitat Politècnica de Catalunya (UPC) in Barcelona (Ing. Josef Holomek and Assoc. Prof. Ing. Miroslav Bajer, CSc. represent FCE BUT in this collaboration) and a General Cooperation Agreement has been signed by the Rector of the UPC (Prof. Colet) and the Dean of FCE BUT (Prof. Drochytka) with an appendix concerning research into composite concrete/steel sheet slabs (signed by Prof. Ferrer for UPS and Prof. Novák for AdMaS UP). A new system of coupling steel sheet-concrete slabs has been developed at UPC. It consists in making holes in parts of the sheets using a special punching matrix. Punching through the sheet causes pieces of metal to stick out of it which have high shear resistance after concrete has been poured over them. This system is protected by a patent. In March 2015, a delivery of sheet metal for test samples prepared for concreting was received from UPC. The Eurocol 60 and Eurobase 106 sheets were delivered from the manufacturer Europerfil, with whom the UPC cooperates in the area of development and the implementation of results in practice. A total of 9 samples for bending tests and 39 samples for shear tests were delivered and concreted in May 2015. The samples with Eurobase 60 metal sheets had been tested completely by the end of year 2015, and some of them were tested in the presence of Prof. Ferrer from the UPC. Evaluation of the results and the preparation of a common publication using the obtained results are currently under way. Simultaneously, another series of slab samples is being prepared at Europerfil which will be sent to the AdMaS Centre for testing.

In Madrid, cooperation was formalised in the area of research, development and innovation between two Spanish organisations, the Spanish Railways Technological Platform (PTFE) and the Administrator of Railway Infrastructures (ADIF), and their Czech counterparts, the Czech Technology Platform Interoperability of Railway Infrastructure (TP IŽI - the Faculty of Civil Engineering in Brno is a member of this organisation) and the Railway Infrastructure Administration (SŽDS) by the signing of a Memorandum of Understanding (MoU). This will enable collaboration in the aforementioned areas as well as the exchange of information and support for the development of projects. The Faculty of Civil Engineering was invited to submit a collaborative project entitled "RAILSEC COST" within the framework of the Cost programme.

In the area of the "Development of durable and auto-adaptive structures on the basis of Performance Based Design and/or Life Cycle Design" the following activities were performed:

- Launch of the production of a theoretical background for methods of reinforcing historic structures in the area of arch rings. The subject of the invention (unique result) is the construction of structural remediation for a brick arched vault with the aid of pre-tensioned reinforcement spatially arranged in the shape of a spatial polygon. In the second half of the year, a licence agreement for the use of the patent was entered into with the company Mitrenga-stavby, spol. s r.o. It is expected to be used within the following years in the area of the stabilization of historic and national heritage buildings, and the extension of their lifespan. The result and fulfilment of this agreement are in accordance with the pre-defined aim of the Applied Research Centre as the aim describes. "Knowledge will be gained aboutthe real behaviour of contemporary masonry load-bearing systems of building and engineering structures reinforced and stabilized by additional reinforcement, as well as about the behaviour of shallow foundations of historic and natural heritage structures when reinforced via their expansion with the use of pre-stressing."Rozpracován postup vedoucí ke stanovení míry spolupůsobení trhlinami oddělených částí mostních kleneb.

- Work began on a procedure leading to the determination of the degree of mutual action via cracks in separate parts of bridge arches.

- A numerical model was created with the help of the FEM (rod element with layers of reinforcement) for the multi-criteria optimization of the design of load-bearing elements fabricated from reinforced concrete for deterministic calculations (an article with the results of the multi-criteria optimization of a tunnel lining was sent to the CESB 2016 conference).- An important research result (project TA03030851 – Rehabilitation of tunnels – technology, materials and methodological procedures) is a newly developed grout with a variable elasticity modulus intended mainly for the rehabilitation of sandstone masonry. This grout is designed in such a way that its elasticity modulus is related in a certain manner to the elasticity modulus of the grouted masonry. This limits the tension in the cleft itself and at the interface between the lining and the grout, thus preventing its mechanical degradation.

- Evaluation and generalization of the results of experiments in the area of additionally emplaced anchoring elements for concrete, and also that of the details and connectors of construction elements of steel (provisional) bridges and footbridges. Analysis of the behaviour of composite metal sheet – concrete slabs and the reinforcement of steel-concrete beams using FRP composites. Experimental verification of details and connectors fabricated from composite FRP-based materials.

- Realization of a programme of experiments aimed at verifying the structural details and glued connections of bridge decks made from composite materials (based on FRP): execution of 5 sets of experiments for approx. 20 pieces for various configurations of geometric parameters - evaluation of results (determination of the stress intensity and the maximum design load-bearing capacity based on the Design method according to tests performed in compliance with the EC). Experimental verification of the behaviour of composite metal sheet – concrete slabs with the use of "small-scale tests", including the evaluation of results using the composite section method. Initial analysis in the area of the reinforcement of steel-concrete beams under load, reinforced by FRP composites, including the execution of pilot tests.

- Work began on a mathematical analysis with direct input and output links to specific issues from the area of the design and use of advanced materials, structures and technologies. Identification of the main qualitative property of the solution of standard differential equations, functional equations and functional differential equations, partial differential equations, discrete equations and fraction equations. The study and analysis of differential forms and their application in the calculus of variations and general systems of partial differential equations. Creation of numerical methods and computational algorithms for the solution of direct, sensitivity and inversion problems concerning initial and boundary problems in engineering mechanics. Creation of a mathematical and physical description of the microstructure of materials and its influence on the behaviour of advanced materials and structures. The outputs from this part of the scientific research activities will be published in high-impact periodicals and incorporated in the prepared innovative methods for the evaluation, design and execution of durable auto-adaptive structures.

Furthermore, the following activities were carried out in the area of the "Development and verification of methods for the use of materials and structural systems for the construction of traffic structures that are specific in the manner of their loading and the conditions in which they will be operated":

- Within the framework of the fulfilment of this aim, towards the end of 2015 a group led by Assoc. Prof. Klusáčka while taking part in the CESTI programme under the auspices of ADMAS developed the methods DETERMINATION OF THE ELASTICITY MODULUS OF MASONRY USING A SINGLE CABLE STRETCH PRESS – MEASUREMENTS and DETERMINATION OF THE ELASTICITY MODULUS OF MASONRY USING A SINGLE CABLE STRETCH PRESS – EVALUATION OF MEASUREMENTS. These methods can be employed in the determination of the elasticity modulus of masonry for existing masonry bridges in the area of road transport and railways. They can also be used to check the state of existing bridge structures and specify their residual capacity and reliability. The methods were produced in the form of Technical Data Sheets for the CESTI centre of competence whose subsidiary part WP3 was processed in 2015 as part of the AdMaS Centre project. The developed methods will be followed by procedures for their verification in the changeable conditions of bridge supports and bridge arches, and for various directions of stress.

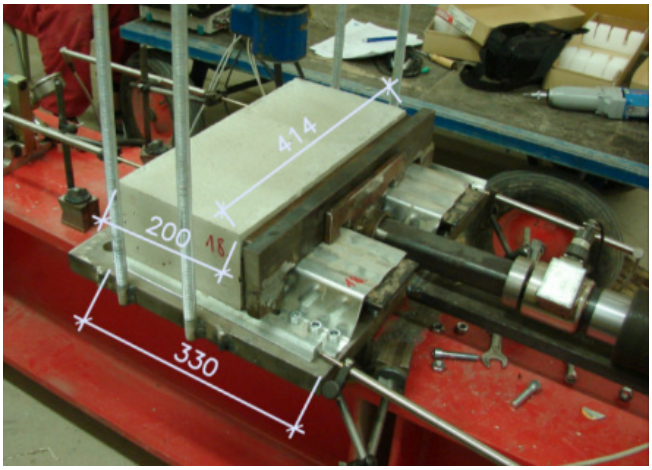
- A method for the prediction of the anti-skid properties of road surfaces with a dependence on traffic load. The quality of the anti-skid properties of a road surface is dependent on the aggregate used for the abrasive layer. The methodology will enable the efficient selection of materials for specific roads and the verification of the sufficiency of the lifespan of the anti-skid properties using laboratory tests.

In addition, a basis will be created for a database of surface properties of roads, and of used materials and technologies. It will be used for the selection of the most suitable materials and technologies for new roads depending on the intensity of traffic load and composition of traffic flow. It will also be possible to determine the most suitable period for maintenance or repairs and thus lower the costs and improve the quality of the road network.

- The methodology "Decision-making process for the welding and exchange of railway tracks" was produced in cooperation with UAM Brno s.r.o. and submitted for certification in 2016. The composed methodology provides instructions on how to proceed with decision-making and which factors need to be considered during the decision-making process. It lists the basic key factors and supplementary criteria, and provides a detailed economic analysis.

In 2015, the results of research into composite sheet metal-concrete slabs with embossed projections were published. The research focused mainly on the comparison of design methods utilising small-scale shear tests. The contributions present the results of experimental research executed at the AdMaS laboratories at Brno University of Technology's Faculty of Civil Engineering. In this area of research, cooperation has begun with the Universitat politechnica de Catalunya (UPC) in Barcelona, where research into composite slabs has been ongoing for many years. At the UPC, a new system of manufacturing composites has been developed which is protected by a European patent. The UPC is cooperating in the development of this system with important producers of sheet metal for composite slabs such as Europerfil.

Fig. No. 3
Layout of a small-scale shear test(left); Graph of the shear resistance of sheet metal with dependence on the slip between the sheet metal and concrete(right).



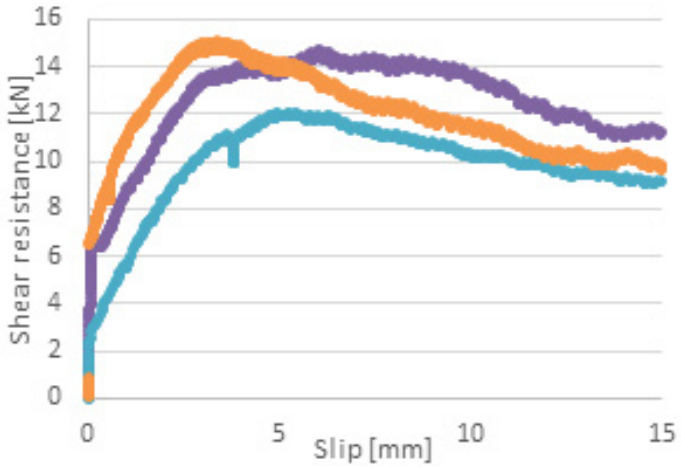
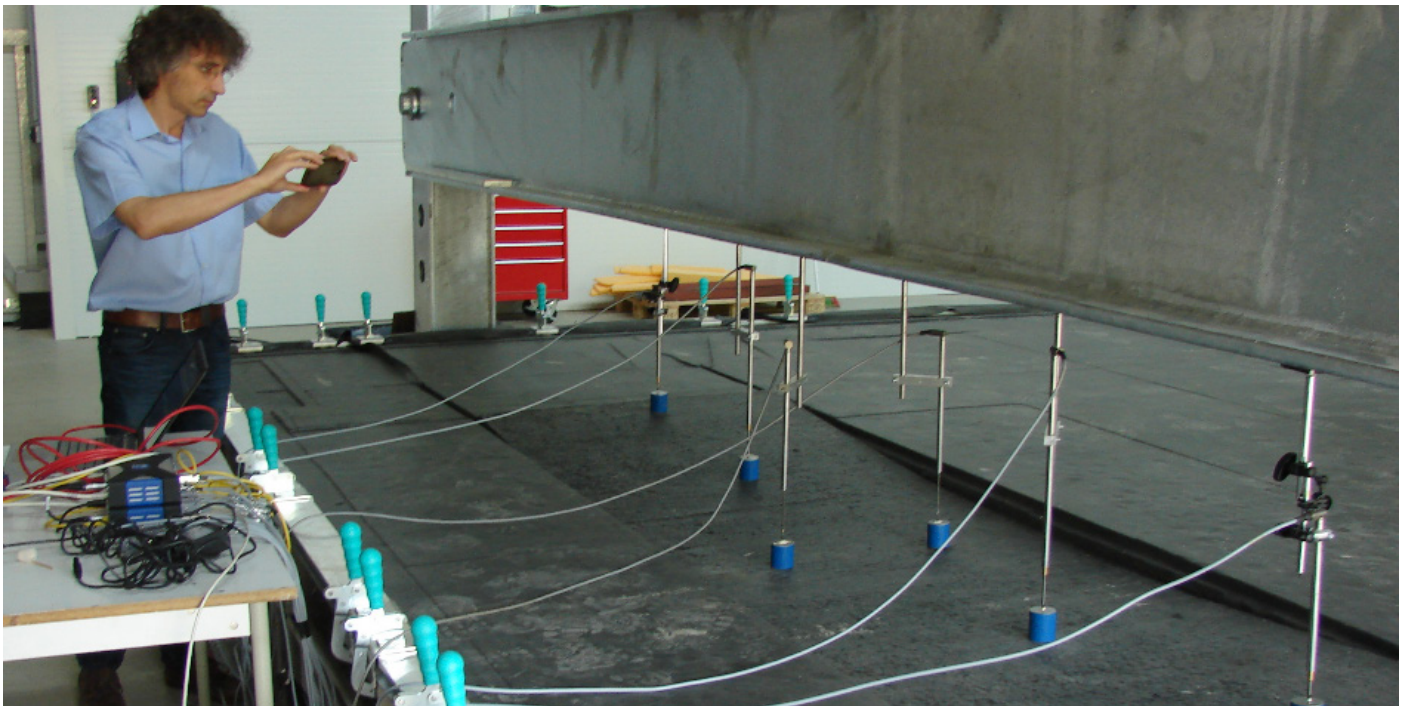


Fig. No. 4
A sheet metal – concrete slab sample with a composite system developed at UPC, under vacuum loading.



Thanks to this cooperation, the UPC has arranged the preparation of metal sheets for test specimens to be used in bending tests, as well as in small-scale shear tests. These metal sheets were sent to the AdMaS Centre free of charge, where they were concreted and vacuum loading tests performed (bending tests using a whole-surface load), as well as small-scale shear tests. Prof. Miquel Ferrer from the UPC was personally present during some of the tests. Their results will be used as the basis for work on shared publications. Currently, Europerfil is preparing samples of a different type of sheet metal profile for another series of tests. In order to be able to present this collaboration officially, a General Cooperation Agreement was signed with UPC Barcelona. Thanks to Prof. Ferrer´s recommendations, some of his colleagues have also proposed cooperation.

Fig. No. 5
Extreme deflections of a composite sheet metal – concrete slab sample.

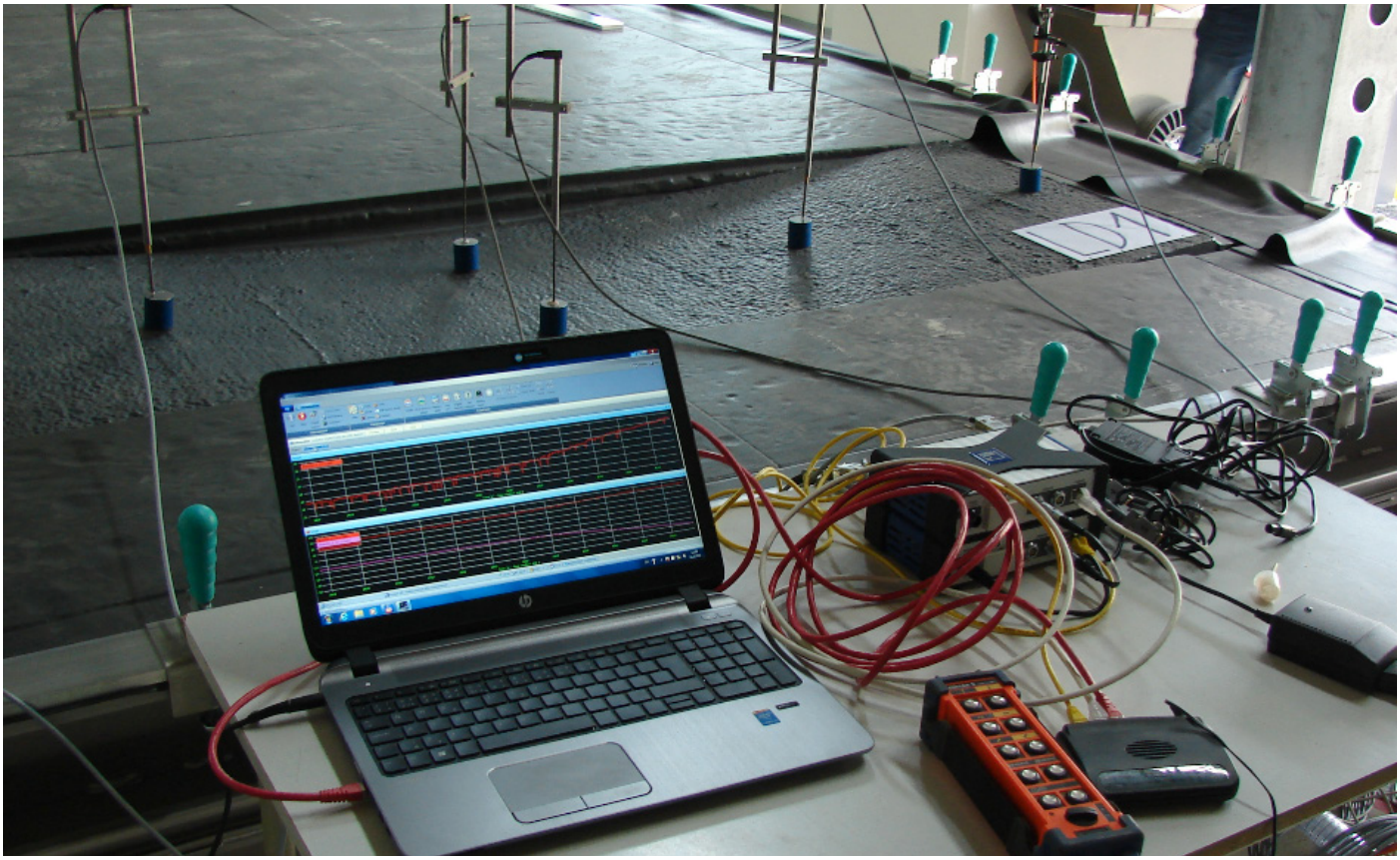
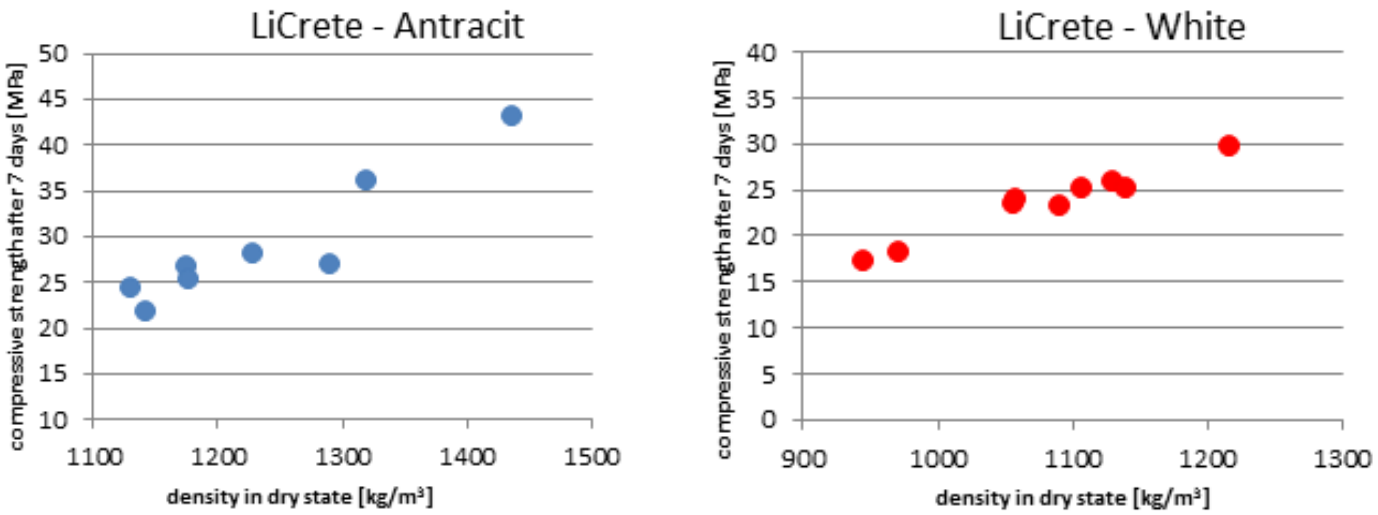


Fig. No. 6
A composite sheet metal – concrete slab sample after failure and removal of sealing film.

An important order was dealt with in the area of the rehabilitation of reinforced concrete structures: HS12557150L – Development of two light matrix variants for LiCrete® design bricks. The contractual research aimed to achieve the suitable lightening of design bricks while maintaining their current properties. A light matrix was fabricated in anthracite and white versions. Several mixtures were designed for both variants. The mixtures displayed a strong dependence between compressive strength and density when dry, as shown in the following graphs. Thanks to this characteristic, it was possible to determine a recipe with an optimum ratio of compressive strength to density. At the end of the work, 5 bricks were produced from each newly-developed light matrix variant and given to the client.

In total, the cement sealant was lightened in comparison with the original variants by 46% in the case of the anthracite version, and by 47% for the white version.

Fig. No. 7
Example of the outputs of contractual research



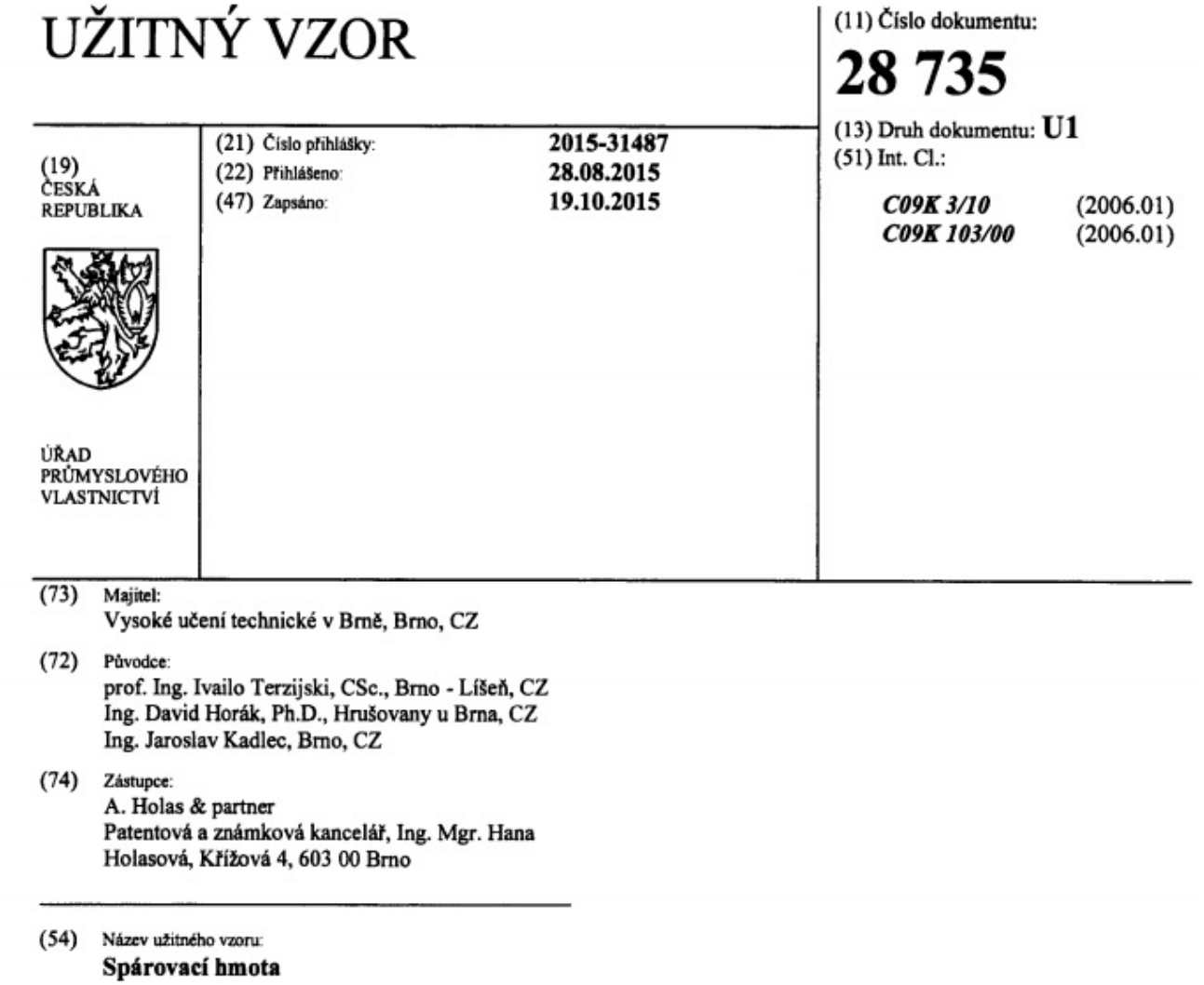
Furthermore, project TA03030851: "Rehabilitation of tunnels - technologies, materials and systematic procedures" was investigated. The research resulted in the development of a new grout. The grout was designed in such a way that a certain relationship exists between its elasticity modulus and the elasticity modulus of the grouted masonry, which limits the tension in the cleft itself or at the interface between the tunnel lining and the grouting material, thus preventing its mechanical degradation.

Fig. No. 8
Photo of the application of patching material

This material enables its mechanical parameters to be changed via the simple adaptation of the recipe, which is highly innovative and advantageous in comparison with commonly available grouts. A variety of types of sandstone or sandstone masonry are to be found in different tunnel structures. Their mechanical parameters are similarly varied, and the grout used for their remediation should have properties which are as similar as possible to theirs. The new material has a variable elasticity modulus which can adapt to the elasticity modulus of the tunnel lining being grouted.

The grout is protected as utility model No. 28735 (see Fig. 9), and simultaneously an application has been submitted for a patent.

Fig. No 9
The granted utility model



UŽITNÝ VZOR

(11) Číslo dokumentu:
28 735

(13) Druh dokumentu: **U1**
(51) Int. Cl.:
C09K 3/10 (2006.01)
C09K 103/00 (2006.01)

(19) ČESKÁ REPUBLIKA

ÚŘAD PRŮMYSLOVÉHO VLASTNICTVÍ

(21) Číslo přihlášky: **2015-31487**
(22) Přihlášeno: **28.08.2015**
(47) Zapsáno: **19.10.2015**

(73) Majitel:
Vysoké učení technické v Brně, Brno, CZ

(72) Původce:
prof. Ing. Ivailo Terzijski, CSc., Brno - Líšeň, CZ
Ing. David Horák, Ph.D., Hrušovany u Brna, CZ
Ing. Jaroslav Kadlec, Brno, CZ

(74) Zástupce:
A. Holas & partner
Patentová a známková kancelář, Ing. Mgr. Hana Holasová, Křížová 4, 603 00 Brno

(54) Název užitného vzoru:
Spárovací hmota

Another implemented project was the TA03030010 – Development of procedures and rules for the design, storage and curing of concretes with limited shrinkage and a low probability of cracking. The main role of BUT's Faculty of Civil Engineering in the project is laboratory testing and analysis of the effects the usage of raw materials have in shrinkage during construction concrete production. In accordance with the main aims in the years 2013 – 2015 the following was achieved:

- A new method for concrete shrinkage monitoring and determination of the level of susceptibility to cracking was developed.
- A corresponding testing equipment was designed and partly manufactured
- A type of low shrinkage concrete was developed and its properties were tested in laboratory conditions and partial-operation experiments.
- A program that allowed the incorporation of the effect of creep (relaxation) of young concrete for the identification of the moment of failure due to shrinkage cracks.

In the field of railway construction the implementation of the TE01020168 CESTI project was carried out. The previously built test section for sprung railway, where pads are fitted under the railway sleepers and sprung anchoring of the rail to the sleeper is used, is still under monitoring. This monitored section is at the railway stations Planá nad Lužnicí, Ústí nad Orlicí and the Havlíčkův Brod – Okrouhlice section. Attention was centred at the slip waves and corrugation development diagnostics this was performed in only selected segments only for small radiuses rails. The properties of the pads were monitored. These pads were fitted under the rail base according to the current standard SŽDC and the currently valid European standards. Different measuring procedures were compared, as well as their impact on the obtained results. The modelling of sleeper placement on the track bed still continues with the purpose of describing the changes in the track bed due to dynamic forces. The track bed modelling was performed using the discrete element method and sleeper modelling using the finite element method. A solution the interface between the two, sleepers and track bed, was developed. As part of the track-bridge interaction monitoring, shifting was measured in selected bridge constructions and one specific bridge was fitted with strain gauges. The rail shift on this bridge was later analysed and the key parameters of interaction between the rail and the bridge, longitudinal track resistance for different types of bridge decks, were determined. A mathematical model of interaction and software for the Microsoft Excel environment were further developed.

Concerning the field of road transport construction, investigations of the properties of road asphalts took place at the AdMaS Center. Attention is centred on changes of properties of binders due to aging. Using the RTFOT device, available at the Centre, it is possible to simulate the aging of binders in a laboratory environment. The changes in the properties of binders are then analysed using state of the art laboratory equipment – dynamic shear rheometers and thermoelectric binding beam rheometers.

Research on the use of rubber granulate, a material obtained from scrap auto tires, on the asphalt pavement of roads took place. Rubber granulate is added to the hot road asphalt, in a quantity of approximately 15%, in order to improve the asphalt quality. The aim of this research is the possibility of introducing this technology in the conditions given in the Czech Republic.

The laboratory equipment designed to determine the slip resistance of road pavements was compared to a dynamic testing device capable of determining the slip resistance properties of road pavements in situ. It is therefore possible to compare data acquired from long term monitoring with laboratory measurements. A relation between laboratory polishing and polishing in real road conditions was also determined. It is possible to convert the number of times a roller passed in laboratory conditions into the number of times a heavy lorries pass in real traffic conditions thus making possible to predict the durability of the anti-slip properties, which will be taken into consideration while designing new asphalt mixes that will increase road safety and at the same time will make the choice of materials available in the Czech Republic more effective.

Fig. No 10
Comparison of the laboratory predicted development of the anti-slip properties with the data acquired from real traffic flow

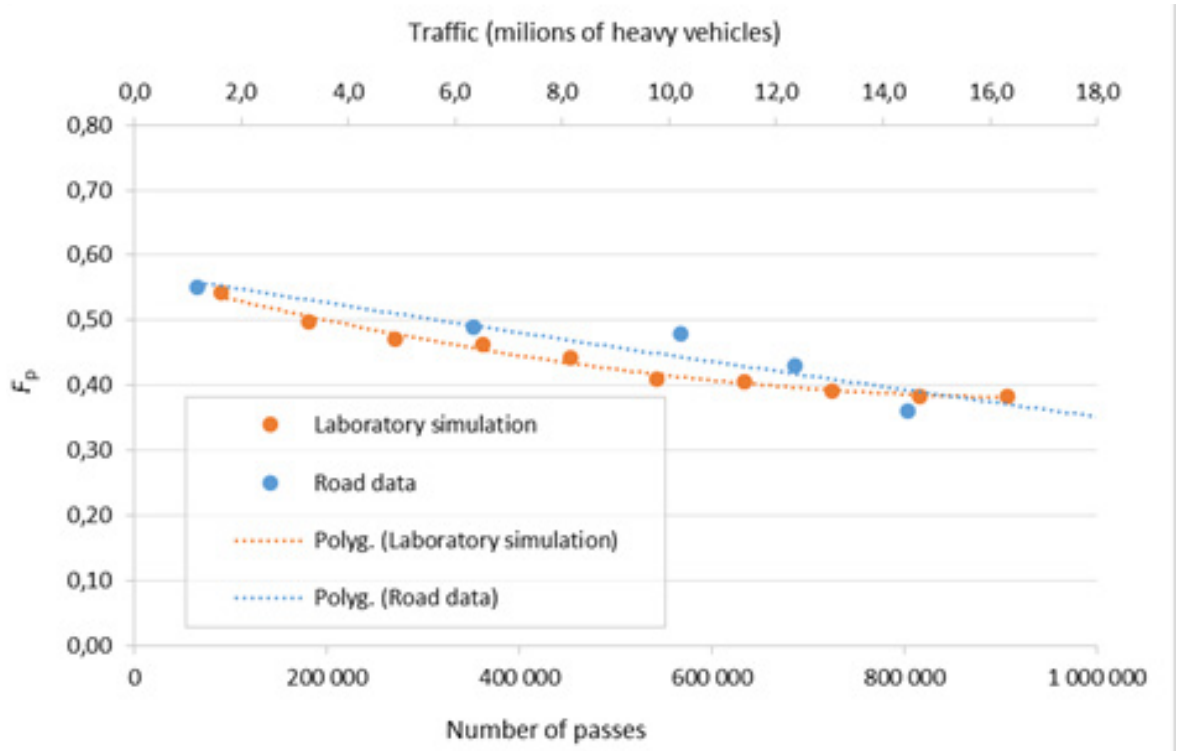


Figure No 11
Equipment designed to determine the anti-slip properties of road pavements after polishing

The Hawkeye 1000 equipment was used to acquire data about road pavements – macro texture MPD (Mean Profile Depth) and the international roughness index (IRI). A database was created, along with other road parameters (anti-slip properties, defects, traffic load, type of asphalt mix, coarse aggregate used, etc.), which will serve as basis for the Pavement Management System. This system will allow a more effective selection of the stretch of road to be repaired and the materials to be used and therefore a more cost effective approach and a more economical use of the natural resources.

The complex stiffness modulus and fatigue characteristics of the asphalt mixes were determined using COOPER equipment – Two Point Trapezoidal Bending Beam Machine. The properties of the different asphalt mixes were determined at different temperatures. The possibility of adding a special geo textile into the asphalt mix that would prevent cracking and its growth was tested. The goal is to design asphalt mixes with a thinner layer and a higher fatigue resistance, which would save asphalt binders and increase the durability of the road pavements.

Fig. No 12
Equipment designed to determine the complex stiffness modulus (left), tested specimen – trapezoid (right)

In the field of building construction investigations focusing on the properties of timber and the behaviour of timber elements and structures took place. In the premises of the AdMaS centre the testing structure EnviHut was built. It is a movable structure based upon the design of a container cell. The floor area is 3 m x 7.5 m and its height is 3.5 m. The structure has its own source of energy. It has a photovoltaic system and a wind turbine for energy production. The design of the structure allows the outer cladding and the roof decking to be changed.

The use of this structure is mostly in the field of wooden constructions, related composite systems and energy (mostly Hybrid and Off-grid systems). In these fields scientific research outcomes are planned for 2016 and the following years.

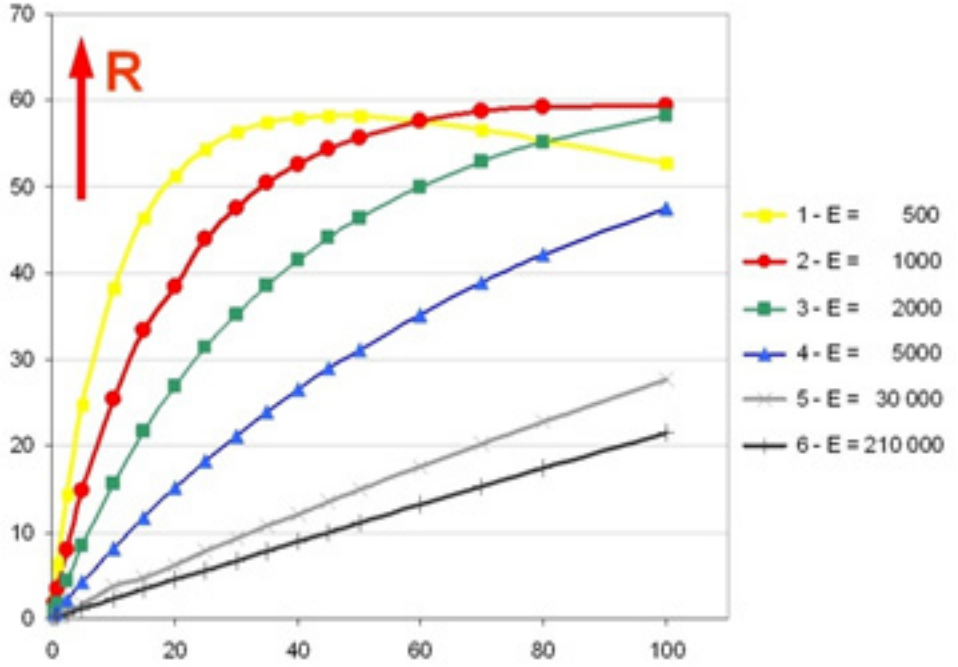
Fig. No 13
EnviHut

In the year 2015, the 15-year monitoring period of the town hall tower of Vyškov was completed and evaluated. This long term monitoring was part of the AdMaS project. The team of authors, led by Assoc. Prof. Ing. Ladislav Klusáček CSc, designed the reinforcement for the current foundations using a (up to that date) non-traditional method that uses post tensioned concrete cantilevers and arches. The structure was fitted with a number of sensors for long term monitoring.

The enlargement, increment in area, of the foundations combined with pre-stressing had been published by Prof. Hruban who assumed split hinge at the junction between the widening cantilevers and the original foundations. The aim is clear – to allow twisting movement of the projected parts and reach a state in which the widening part of the foundation would be pushed towards the subsoil by action of the pre-stressing force. Such a pushing movement has to be accompanied by an upward reaction, at the junction, and therefore by a lowering of the compression at the foundation-subsoil junction. During a more detailed evaluation of the strain on the original foundation, the enlargement (reinforcing) and the subsoil can be noticed that in some cases the use of the hinge is not necessary in order to obtain an immediate activation of the enlargement. A numerical study carried out for the structure, which consists of new concrete foundations and original masonry foundation, showed that an effective compression (pushing effect) into the subsoil can be achieved by elastic compression of the original foundations, especially in the case of masonry foundation whose elasticity modulus is normally much lower than e.g. concrete. The results of the numerical study, carried out by the authors of the reinforcement evaluation of the foundations, are shown in the picture bellow

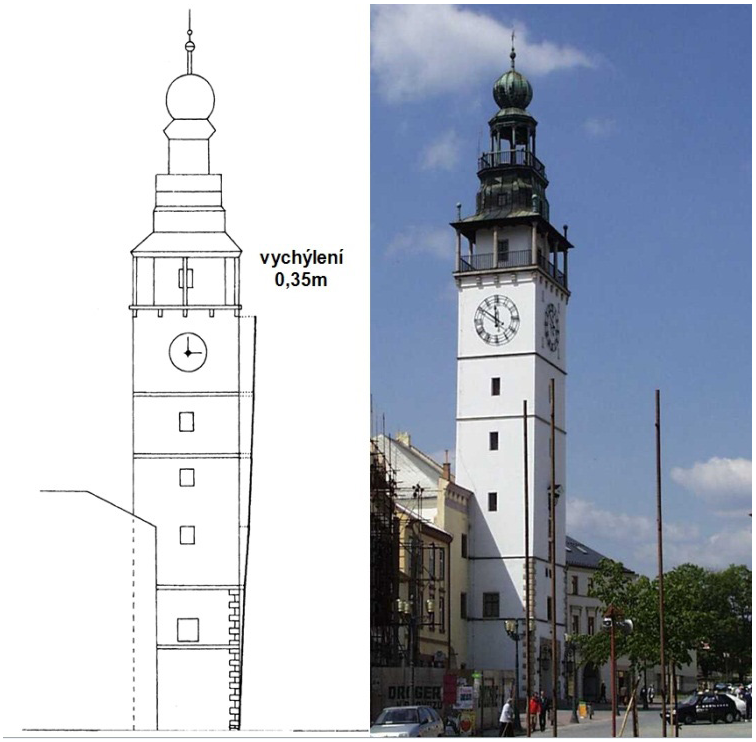
The graph shows the magnitude of the reaction R [kN] originated by post-tensioning directed vertically upwards in relation to the strain modulus of the subsoil for different materials of the original foundations expressed by the elasticity modulus of the material. As comparison the moduli corresponding to steel and high performance concrete are shown, which are not real materials of the reinforced (enlarged) foundations but can describe very well the relation in question. The foundation was modelled as simple, as Winkler. It can be seen that for a very stiff material of the original foundation a relieving reaction occurs in gravelly soils. With the decrease in the elasticity modulus of the original foundation an important reaction occurs already in clay and loess soils, which was the case of the reinforcement of the foundations of the tower approached by the authors. In this type of combination of subsoil and reinforced masonry walls the elastic compression of the foundation wall given by the post-tensioning allows twisting (shift) and with it practically and immediate activation of the embedded foundation strips. In this fashion the foundations of the unstable tower (see picture below) were reinforced. A following 15-year monitoring period confirmed the real existence of pre stressing applied and its long lasting stability. With the above mentioned a high degree of reliability of the proposal was confirmed as well as the actual project.

Fig. No. 14
The magnitude of the reaction R in relation to the strain modulus of the subsoil and for different elasticity moduli of the original masonry foundations



Reaction R [kN]
prestressed enlargement

Fig. No. 15
Deflection of the town hall tower in Vyškov



In the published results the following insight, obtained as part of the evaluation of the AdMaS project, was emphasized.

The previously described structure clearly shows the effectiveness of this method. However, it is essential to join the reinforced concrete strips with the original foundation – that is with the use of pre-stressing. Otherwise this method would not be effective enough. The transfer of tension solely by means of common concrete reinforcing (anchoring) is therefore impossible because the additional reinforcement for the transfer of tension at the joint gap is difficult to anchor to the original masonry. Post tensioning using strands or wires modifies the task substantially and changes tension into compression stress at the joint gap between the old and new foundations. The transfer of the shifting forces is then carried out using shear connectors. Another benefit of post tensioning is the possibility of the immediate reaction of the subsoil. This could be achieved by a suitable, mostly off-centre cable position, which shifts the deflection of the new foundation towards the subsoil. This stops a free deformation from pre tensioning and at the point, where new and old foundations meet, a type of reaction takes place and the compression stress into the original masonry foundations is substantially lowered.

6.2.2. Research activities of the EGAR research group

In the field of the EGAR research group, research and development activities according to the proposed aims of the TA project were carried out.

In the year 2015, cooperation with scientific centres and universities from other countries took place. As an example we can mention the training of the Krmiček Centre staff in Potsdam, where the contact persons were Prof. Dr. Rolf Romer (Deutsches GeoForschungs Zentrum Potsdam) and Dr. Martin J. Timmerman (Universität Potsdam). The preparation of scientific projects and publications was consulted with the above mentioned partners. One of the outcomes of the long term cooperation with Deutsches GeoForschungs Zentrum Potsdam is the acceptance of a joint publication to be issued, with an 8, 235 impact factor, in the Gondwana Research journal. In cooperation with representatives of the Universität Potsdam a proposal for a scientific grant project was created. In the spring of 2016 this proposal will be submitted for evaluation to the German grant agency "Deutsche Forschungsgemeinschaft".

In the field of research of the VS EGAR the following scientific research activities were performed:

- Ensuring cooperation for the development project of the "swim trainer" with NIVEKO, s.r.o. focusing primarily in the proposal of changes and testing of the prototype of the swim trainer with the required parameters as defined in the research contract. Based on the prototype testing some changes in the construction design of the prototype and the driving mechanism were carried out by VS EGAR.

- The contract research in the use of the most updated technological knowledge in the field of waste water treatment, prognosis of region development related to the most cost effective operation of waste water management plants.

- The contract research for the use of carbon obtained from pyrolysis – the treatment of sludge from municipal and industrial waste water management plants, after-treatment of waters (elimination of xenobiotics, pharmaceuticals, endocrine disruptors, personal hygiene products, pesticides, etc.), elimination of ammonia from drinking and waste waters.

- In the process of application for grant: the use of microwave pyrolysis of waste water sludge as a renewable source of fuel and energy

- In the process of application for grant: AOP technologies for the elimination of toxic substances from cleaned (treated) waste waters

- In the process of application for grant: the elimination of chemicals otherwise difficult to eliminate from waste waters using wood-decay fungus

- Contract research in the field of advanced strategic management – input study "Smart City"

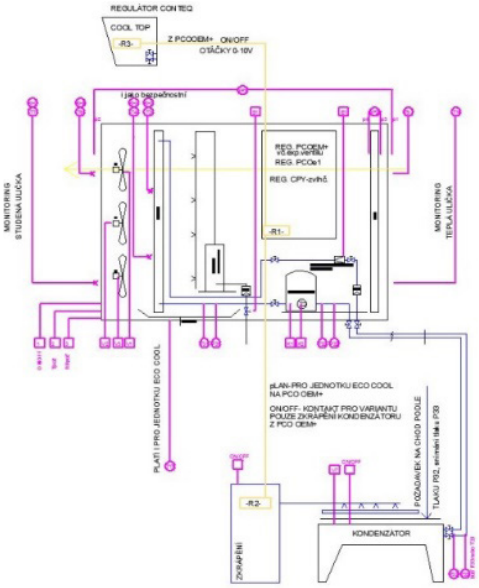
- Development of platform "energy management" for its application in the field - public and industrial sectors

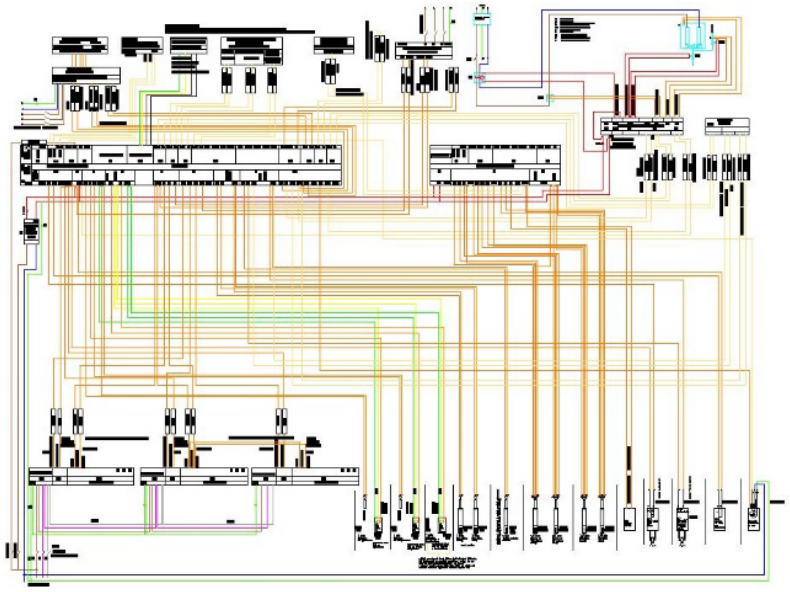
- Contract research in the field of mathematical analysis of sound silencers (chimney attachments) produced by Schiedel with the outcome of an integrated selective software tool for their design. The SW has for each silencer the calculation of sound damping in each frequency band, the calculation for the sound of the silencer itself, the calculation of the pressure loss of the silencer with graph and the calculation of the sound pressure level where the listener stands.

- Development of a functional prototype of a special cooling loop, which will be used to cool down server rooms or entire data centres. The development is based upon CFD simulations of air flow, simulations of the cooling performance of each geometry of the evaporators

Fig. No. 16
Measurement and data analysis process

Fig. No. 17
A selection from the preparation of the cooling equipment (left), plan of the command unit and connection of parts of the equipment (right)





- Research of the isotope composition characteristic of geo materials
- Participation in the preparation of the project proposal for the use of highly efficient geothermic sources as part of the project "International programme of deep drilling in the continents"
- Acquisition of complex insight about the geotechnical potential of the Brno and Třebíč rock massive, related to this is in stage of project proposal from OP PIK "Partner cooperation between GEOtest and the regional centre AdMaS" with the goal of detecting and solving geological problems vs collector and IG network, setting the mechanisms of elimination of negative effects and determining the limit values of the monitored parameters. Acquire new insight from the geotechnics field based on practical skills from in-situ measurements as well as laboratory testing, including work with modern laboratory equipment as well as complex or mathematical modelling of the generated data, establishing a monitoring method and SW development.
- Contract research for bridge anchors' tensioning at abutments.
- Testing and checking of a data system for data input, monitoring and evaluation of the technical condition of waste collection points in Brno. It also includes the updating of technical certificates of the container stations.

- Contract research in the field of experimental design and testing of technologies capable of processing black and white aerial photos with the purpose of testing the non-standard archive photo processing including the supplied connecting points and ground control points and the given elements for inner and outer orientation.

- The possibility of using a mobile mapping system in order to analyse total budget, repair and maintenance cost of roads.

- The possibility of using a mobile mapping system in regions with poor GNSS signal – testing in the Moravian Karst region.

- Contract research in the field of drones deployment in power distribution operation environment.

- Contract research in the field of ground scanning aiming to obtain safety and fire protection documentation of the underground spaces.

- In the application stage for a grant – development of SLAM method (simultaneous location and mapping) comparison of the effectiveness of the mobile mapping system and industrial cameras with practical use in civil engineering, urbanism, architecture and industry

- In the field of "Development of new technologies of wastewater disposal and management, treatment of drinking water and its distribution, waste management, development of new procedures for the use of energy from waste waters, waste and sludge created during waste water treatment" concerned the development of a membrane cleaning unit for grey water in a detached house. Optimization of the operation and possible waste heat usage produced by grey waters. Testing performed in a detached house.

- In the field of "Measurements of the heat and micro climate properties of buildings and parts of buildings (including their properties related to their internal and external conditions) with the aim of a proposal for a building methodology and a production technology of construction elements for achieving optimal energy and other parameters" a Czech Science Foundation project was proposed in the year 2015 related to the topic of refractive facades and their impact on the microclimate of buildings (the project was chosen to be implemented from Jan 1, 2016). Furthermore, a specific research aimed at the thermal stability of buildings in the summer months took place and for that purpose 4 testing units for the evaluation of the thermal stability with variable composition of the perimeter cladding were built in the open premises of the centre.

- The issue of testing of the membrane cleaning unit for grey waters was dealt with. Measurements of flow, electricity and air consumption were carried out. A calculation model of grey water using the membrane unit was proposed and the reliability of the membrane unit was dealt with. The operation of the cleaning unit was optimized. Measurement of the temperature of grey water in order to evaluate the possible usage of its heat took place. The efficiency of the membrane was monitored. An adjustment of the standard regarding the treatment of grey and rain water in buildings was proposed.

- In the field of "Implementation of geodetic, photogrammetric and metrological support of building construction and research (surveying of buildings and natural spots, creation of 3D models from aerial and earth sensors – aerial scanner Lidar, earth scanners, bundle of cameras, determination of the exact geometry of individual elements, structures and buildings, small scale and large scale calibration). Determination of the absolute spatial position of buildings and other construction objects, monitoring of their short and long term changes with the use of global positioning satellite systems (GNSS – GALILEO – GPS – GLONASS)". Contract research took place in the field of surveying and aerial photography where the most important cooperation took place with the company Hansa Luftbild AG. Also testing of the use of GNSS systems took place for example in the field of railway building. The project NAKI was submitted. This project deals with the use of modern surveying methods in the field of monument preservation. Based on parts of research projects and contract projects we analyse the possibilities of usage of photogrammetric and laser methods in energetics, transport and building construction. In the field of energetics it is the testing of drones for monitoring high voltage pylons without being disconnected them from the power supply. In transport construction we analyse the alternative possibility of monitoring road surface defects and also the verification of the methodology to determine the spatial position of tram tracks. For the field of building construction we are working on the construction of a device that uses the method of simultaneous locating and mapping; this can be used mainly in the technology of building information modelling.

- In the field of "verification and development of new technologies for wastewater treatment and drinking water treatment" the testing of a new regeneration unit BIONIC is under process. The unit is located in the hall of Pavilion 4.

- In the field of "Development and verification of methods for the verification of practical field applications and laboratory measurement, evaluation (including mathematical modelling) and the development of methods in the field of geotechnical methods of research and diagnostics of foundations, from the point of view of building design, restoration and analysis of their durability". In the year 2015 a certified methodology "Methodology of quality testing and level of improvement of the subsoil using gravel pillars" was issued, utility model "Testing field for the verification of the gravel pillars" (registration No. 28937) and utility model "Fast setting injection mix on the basis of silicate resistant to dissolving" (registration No. 28686).

- In the field of "Development and verification of methods for the measurement of thermal and microclimatic properties of buildings and parts of buildings (including their properties in regard to outer and inner properties) with the aim to propose methodology of construction and technology of production of construction elements in order to reach optimal energetic and other construction parameters" the project Smart City is currently in progress. "Intelligent regions – building and settlement information modelling, technology and infrastructure for a sustainable development" also the development of new measuring devices for monitoring and data collection related to the condition of the environment and temperature and the humidity of structures materials.

- The field of BMI is being addressed within the project Centre of Competence of TACR ČR TE0200077 (see MI 0603); two BMI international standards adapted for the Czech Republic and a pilot web version for the creation of a National BMI Library in the Czech Republic was created. http://www.narodni-bim-knihovna.cz/kategorie-stavebn%C3%ADch-v%C3%BDrobk%C5%AF-eu-3052011.

Examples showing how the infrastructure and the equipment have been used by the VS EGAR:

- **Supply and instalment of a complex geotechnical monitoring system** – Used by the geotechnics group. The geotechnical monitoring system was acquired in order to detect and solve problems of structures in complicated natural environment appropriately and to adequately set the mechanisms of detection of negative effects, which requires to set the limit magnitude of the monitored parameters. The installation of the monitoring elements took place in the premises of the experimental polygon of the experimental controlling geotechnical monitoring system which was built for selected segments of the primary collector in Brno (detection and problem solving of the rock bed vs. collector and IG network). The geotechnical group, using numerical modelling, interprets the data acquired from the monitoring system. It will be possible to detect signals for each individual sensor more accurately and set warnings that have a key role in the usefulness of the monitoring system. The researchers can therefore acquire new knowledge from the geotechnical field by field measurements performed on-site, or laboratory measurements which includes work on the most advanced laboratory equipment as well as complex or mathematically generated data. Knowledge can be also acquired by establishing methods of monitoring and SW development. In cooperation with GEOtest Brno, a.s. a project was submitted to the OP PIK, Partnership of the knowledge transfer with the aim of transferring the theoretical knowledge into the applied sphere. This will lead to a methodical procedure during the design of underground structures using a combination of mathematical modelling – advanced material model. It will also lead to the implementation of a SW tool and a numerical model.

- **Data infrastructure used by the whole EGAR research group.** The data infrastructure was installed in the server room of the AdMaS centre with the required additional conditions (power supply, cooling, safeguarding by UPS technologies) and is used as data storage and management of the acquired network licence SW VS EGAR, as data storage (e.g. data packages acquired by the mobile mapping system and the LIDAR system), as a publication server (e.g. platform similar for instance to BIM library, which is the outcome of the TA ČR TE0200077 Centre of Competence Smart Regions project).

- **Multifunctional device or the energy analysis TEB II** – used by the research group energy analysis of buildings and regions. It is a set for measuring properties of indoor building environment; in particular, a set of data loggers (sensors) which can be connected to a PC for measuring temperature, inner environment humidity and CO2 concentration inside buildings. The sensors and data loggers are currently used for the implementation of TA ČR TE0200077 research project Centre of Competence Smart Regions. Cooperation was going on involving theoretical solutions to the innovation technologies in technical systems in buildings on the pilot location Brno – Nový Lískovec. Models of building are ready for interaction with distribution energy net in theory and consequently in pilot implementation. Next, sensors and data loggers are used for implementation of contractual

research in the area of strategy design Smart City to be used for design measures of property optimisation of inner environment of public buildings - such as schools, municipal offices etc.

- Calibration facility – Calibration facility serves the exclusive purpose of mobile mapping system calibration; the system would supply erroneous planimetric information without proper calibration; it is necessary for proper operation and the consequent work with cloud point.

- Devices with a PC connection and sensors measuring flow, temperature, convection velocity, humidity, solar radiation and concentration of substances. Used by the research group energy analysis of buildings and regions. The sensors are currently used for experimental work in AdMaS Centre for observation of selected parameters in Building P4, which is among the pilot location within the implementation of TA ČR TE0200077 research project Centre of Competence Smart Regions. These sensors are used also in experimental buildings constructed in AdMaS Centre during the specific research of observing thermo-insulating property influence on temperature development in the upper casing. Observing the selected parameters in Building P4 helps with developing the "energy management" platform to be used in application area – communal area and industrial companies. Grant project of contractual research in DONE, s r.o. in preparation stage.

- Delivery of equipment for stationary analytic laboratories of urban engineering technologies – it is used mainly for water analyses as a support for ongoing research in the area of urban engineering – see above.

- Anaerobic reactor with a membrane separation pilot device (AnMBR) – used by urban engineering group – the anaerobic reactor pilot device was being tested from 01/2015 to 04/2015 on the AdMaS – Building P4. Since 05/2015, it has been installed in Černá Hora brewery for industrial (food industry) wastewater treatment within the BUT specific research implementation. Based on the pilot testing results (contamination removal efficiency, membrane clogging, biogas and sludge production, power consumption), the operation of AnMBR is continuously optimised (changes in operating parameters) and maintenance or cleaning is performed. The monitored parameters are intake and discharge quality (BOD, COD, NL, N and P), the amount and quality of produced biogas, the production and composition of sludge. The monitored operational parameters are transmembrane pressure, permeability, flux, pH, residence time, power and chemical consumption and amount of injected gas (mixture stirring and membrane washing). The efficiency (values and contamination removal efficiency) and reliability of the cleaning process (tendency to membrane clogging and membrane degradation) are determined as well as the specific production of biogas and its quality in different operational environments. During the implementation stage these parameters are being monitored in mesophilic (25-37°C) and thermophilic (45-60°C) environment. The pilot unit will be delivered on location by 06/2016. At the end, a final assessment of AnMBR efficiency will be prepared (the available discharge quality, costs per m3 of treated wastewater – power and chemical consumption, biogas and sludge production). The obtained results of AnMBR operation will be compared with conventional technologies for treating industrial wastewater.

6.2.3. Research activities of the Mathematical Modelling Research Group

In 2015, the research activities of the Mathematical Modelling Research Group proceeded in accord with the aims of the Technology Agency project.

At the end of the year 2015, a prearranged agreement of collaboration between the scientific teams of the Brno University of Technology (BUT) and the Vienna University of Technology (TU Wien) was signed. The said collaboration focuses primarily on examining of quasibrittle materials fracture, determining relevant values of fracture-mechanical parameters of models used in structure analyses and on describing materials in terms of fracture propagation, including the description of their fracture process zones. The collaboration includes experimental campaigns, detailed numerical analyses and also advanced evaluation of fracture test results. The achieved scientific research results are to be summarized and published. The collaboration will proceed under the supervision of Prof. Ing. Zbyněk Keršner, CSc. (BUT) and Dipl.-Ing. Dr. techn. Ildiko Merta, MSc. (TU Wien).

Furthermore, we continued working on developing a probabilistic assessment methodology. It relates to testing and determining of material parameters of concrete, statistical evaluation of test results, including subsequent estimation of characteristic and design values and mathematical modelling of time-dependent degradation processes of concrete, incl. reinforcement corrosion on the stochastic level and reliability analysis. The original methodological concept, which consists in a fully probabilistic assessment of existing concrete road bridges, has been expanded to include estimation of the load capacity for the given residual lifespan with respect to how old the individual bridge structures are and how the degradation processes of concrete and reinforcement corrosion are advancing.

The fully probabilistic assessment methodology was used to determine the current load capacity of a bridge over the River Sázava which was built in 1953 near the village of Utín (reg. no. 03818-3). Taking this bridge structure's age of 60 years into account, the same methodology was further used to estimate its load capacity for residual life spans of 15, 30 and 40 years. The assessment of the normal load capacity of the bridge in the examined time nodes of 60 years, 75 years, 90 years and 100 years was carried out on the global level of the structure, on the basis of statistical evaluation of 25 virtual FEM simulations of structure fractures for the given load effects with the vector of random variables generated by the simulation method of Latin Hypercube Sampling. The values of normal load capacity were determined for the required reliability level corresponding to the limit load capacity and serviceability which was defined by the guideline value of the reliability index. The following guideline values of the reliability index were used: 3,8 or 3,1 for 3rd class road bridges for limit load capacity, and 1,5 or 1,3 for 3rd class road bridges for limit serviceability states for irreversible phenomena. The values of normal load capacity, determined by using the probabilistic analysis in the individual time nodes, are shown in Fig. 19. They were obtained on the basis of the assumption that structure response has a lognormal probability distribution. These results were presented at the conference Bridges 2015 which was held in Brno (Doležel et al.).

Fig. No. 18
Bridge reg. no. 03818-3: side view (left), cross-section of the bridge (right)

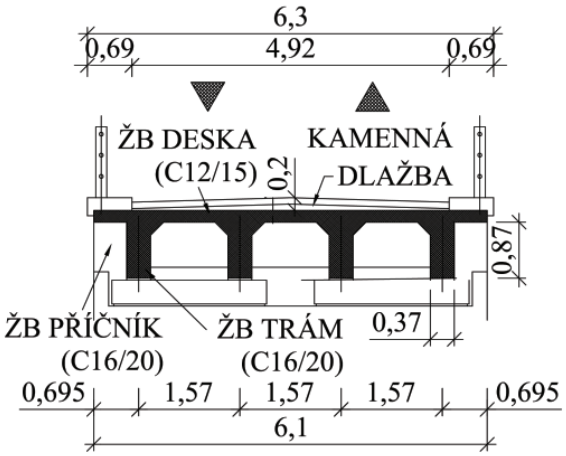
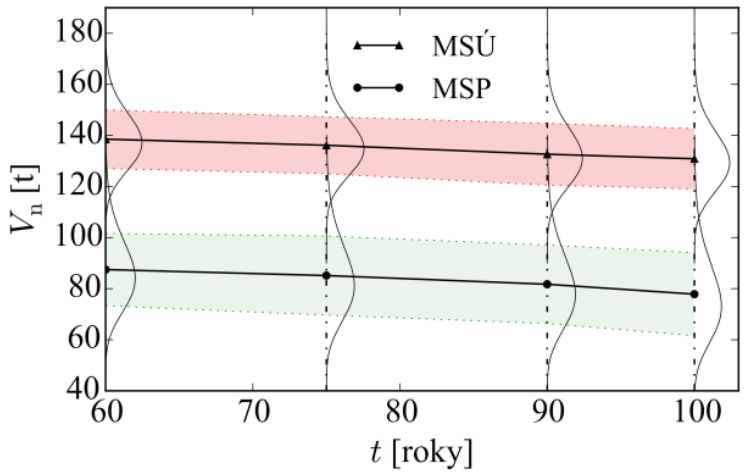


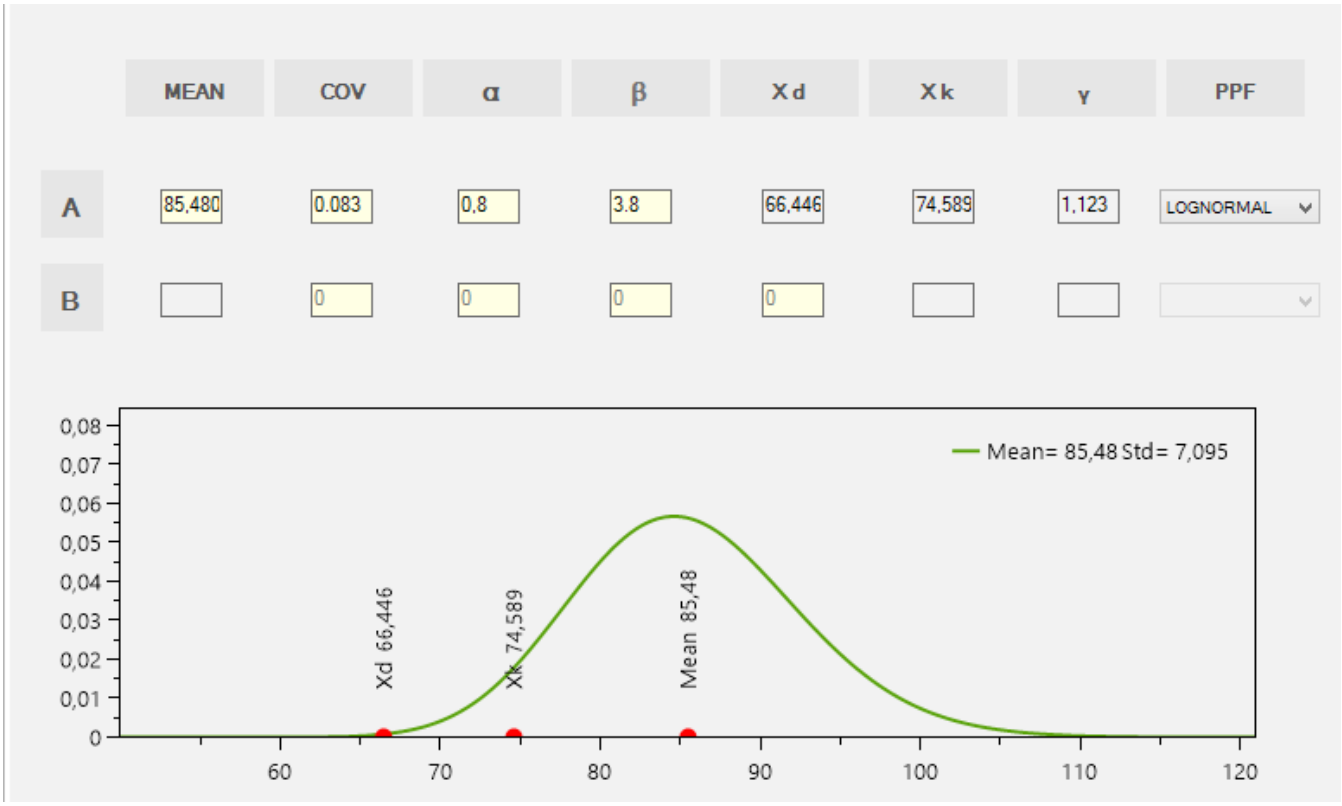
Fig. No. 19
Changes in normal load capacity for limit load capacity and serviceability in the course of time



In 2015, our research team created IO-SUPPORT, a piece of support software which is intended for determination of load capacities and enables visualization of the fully probabilistic approach and standard procedures. The software has two main functions (INPUTS and RESPONSE) which are organized in two types of tabs:

- calculation of individual unknown input quantities – tab INPUTS (Fig. No. 20), and
- visualization of load capacity of structures based on the FReET / SARA / ATENA program data – tab RESPONSE.

Fig. No. 20
Program IO-SUPPORT – tab INPUTSProgram IO-SUPPORT – záložka INPUTS

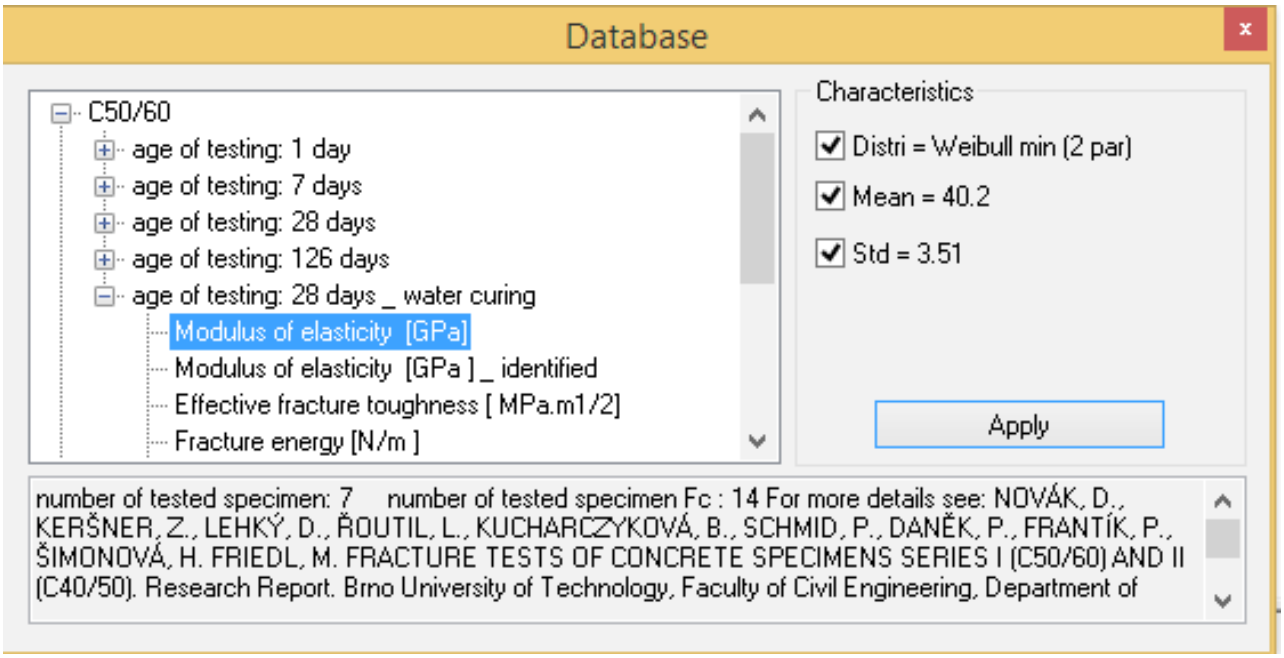


Analyses of mechanical response / damage of quasibrittle material structures must always include fracture process zones which emerge in front of the crack tip, causing specific nonlinear behavior. Thus, it is essential to be familiar with fracture-mechanical parameters of the material which is being analyzed. The established fracture-mechanical parameters can be used for quantification of a composite's crack resistance / crack propagation or its brittleness / toughness. Furthermore, they can be used as correlation parameters of the studied concrete composites (i. e. components / structures after implementing a dimension which takes geometric characteristics of structures into account); finally, they can be used as a part of the input data for numerical models of quasibrittle material components' / structures' behaviour (based on the finite element method including implemented principles of nonlinear fracture mechanics), either on the deterministic or the stochastic level. The procedure described above is to be supported by a database which has been implemented into the FReET software and includes fracture-mechanical parameters of a number of different kinds of concrete of selected strength classes. The database comprises results of extensive experiments. The fracture-mechanical parameter values were established by using records on load-displacement relationship in the middle of a notched beam span. For determining of some selected parameters (e. g. modulus of elasticity, tensile strength and fracture energy), identification methods were used as well – thus, when searching for data concerning these parameters, database users are able to make use of both the experiment results and the results obtained by identification methods. The database is hierarchically organized into three levels:

- Level 1 – **Class of concrete**.
  - Level 2 – **Age of concrete**
    - Level 3 – **Individual parameters**.

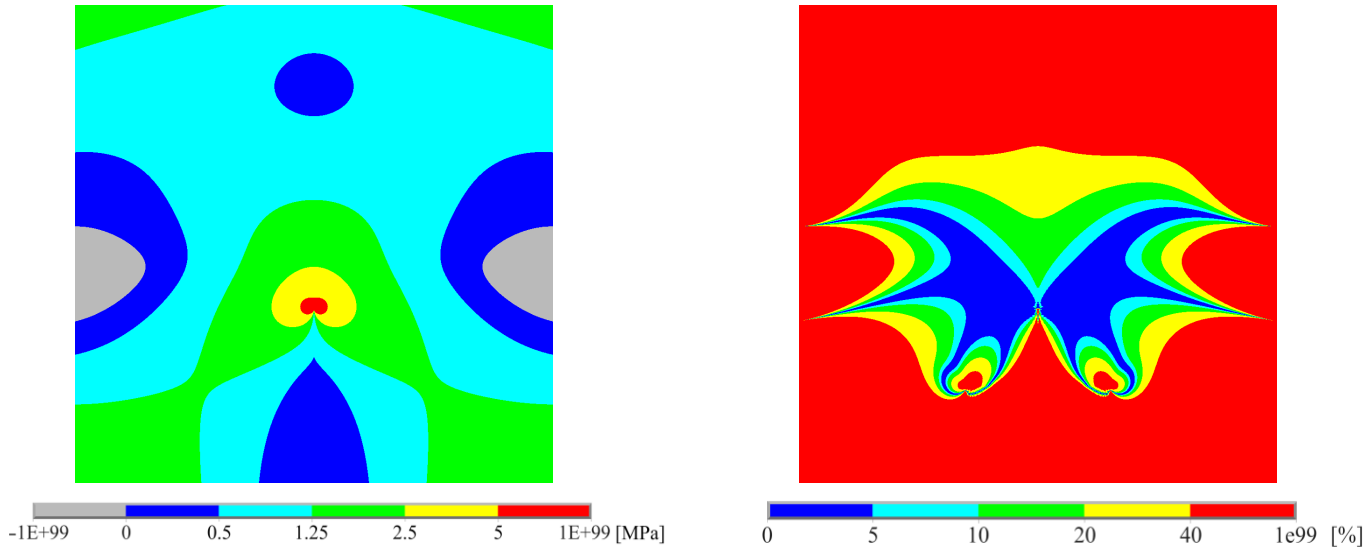
For each parameter, a suitable probability distribution model and some basic statistical parameters are defined, providing support for creation of probabilistic models. Fig. 21 shows a view of the database in the FReET program.

Fig. No. 21
View of the database in the FReET program



A significant part of our research activities focused on the description of stress and displacement fields in solids with a crack. For this purpose, Williams' power series was used. The acquired descriptions are then further used in various kinds of fracture-mechanical analyses. The values of coefficients of the power series terms are determined by a technique based on the least squares method from the elastic FEM solution results. Subsequently, the values are used for reconstructing these fields while only a finite number of terms in a series are considered. That way, approximations of these fields are gained (see Fig. 22 on the left, where a stress field 1 is shown, with the crack tip being situated in the red area – 7 terms of the series were used). Such approximations are very accurate when conducted near the crack tip; however, the further from the crack tip, the less accurate the approximations tend to be (see Fig. 22 on the right, where a percentage deviation of a stress field approximation 1 from the FEM solution is depicted; the figure relates to Fig. 22 on the left).

Fig. 22
Stress field approximation in solids with a crack using the Williams' power series (left), approximation accuracy (right)



Furthermore, we focused on numerical simulations of fracture tests, concentrating especially on the assessment of energy dissipation distribution in the course of fracture processes (by means of acoustic emission scanning), and also on determining calibration curves to establish fracture parameters.

The numerical study of the wedge splitting test which was included in the previous report (an article on the mentioned wedge splitting test will be published shortly in an impact factor journal) has been expanded so that it will be possible to use its results to formulate a set of recommendations for conducting experiments while

eliminating most of the negative side effects. Various testing options are being investigated, with respect to the proportions of the solid and the type of boundary conditions.

Our scientists succeeded in designing and manufacturing of several devices intended for conducting wedge splitting tests. They include a wedge to be attached to the trial press's crossbeam, cover plates with bearings to be inserted in the specimen's mortise, and shift meter holders to be mounted onto cover plate pivot pins. These devices were reported as functional specimens.

Furthermore, the stability of slim steel structures was studied. For nonlinear structure-mechanical systems consisting of more interactive elements, we created a number of stochastic computational models which can be used to perform reliability analyses. We developed numerical analyses based on the Monte Carlo and Latin Hypercube Sampling methods. Also, we optimized existing computer programs in such a way that calculating of coefficients is now done most effectively by using the CPU. We identified situations in which estimations of nonlinear computational model parameters are accurate enough to provide reliable predictions of structural failure. The input variables whose impact on the model output appears to be rather negligible were filtered. On the basis of sensitivity analyses' results regarding structural model responses, we created several stochastic computational model variants, in which grouping of the domains of definition of the input variables, which are essential for reliability, was taken into account. Reliability analyses performed in the grouping models identified and quantified random variable interactions. Further, the impact of deterministic parameters of nonlinear computational models was investigated, along with the accuracy of statistical characteristics which is essential for reliability analyses' results. Thus, we were able to simplify and to decrease response times of computational models based on virtual simulations.

We also continued working on the development of numerical methods for integration of probabilistic functions using the Monte Carlo method. Having corrected the so-called Audze-Eglajs criterion, our experts now succeeded in correcting both the MaxiMin and MiniMax criteria by means of periodic extension. All the corrected criteria mentioned above are used for placing integration points in the unit hypercube. It was proved that in comparison with the formerly used procedures, they lead to significantly improved results. Furthermore, we created a methodology and an algorithm which allows very fast and completely accurate quantification of the uniformity criterion value for regular orthogonal grid (raster) patterns in the unit hypercube of any dimension. This is very important because it enables to determine the minimum value of a criterion; if we know this minimum value, we are able to significantly improve convergence of heuristic combinatorial algorithms which are used to optimize existing designs.

An article of ours, dealing with modelling of fracture damage in concrete by using a probabilistic discrete model, was published in a prestigious scientific journal. Aggregate grains and surrounding matrices are represented by discrete, perfectly solid polyhedrons. On the polyhedron contacts, a constitutive law is defined. The constitutive law parameters are considered random and they change according to the random field realizations. On comparing the results of the model with our experiment results, the model proved to be excellent in terms of its predictive abilities. Our researchers focused on investigating of the impact of a random field autocorrelation length on the strength of a structure or a test specimen. It seems that autocorrelation length has a different impact on solids without a notch and on solids with a significant stress concentrator. We presented these preliminary results at the CFRAC conference in Paris.

Our research team also further explored the classical topic of approximating the strength of fragile fibre bundles whose random strengths are subject to the Weibull distribution. We were able to program a unique algorithm which enables to precisely calculate the value of the bundle strength distribution function and can be used for bundles consisting of up to approx. 6000 fibres. The program is truly unique because it makes use of the recursive relationship which can be - without any modifications - applied to bundles of no more than 20 fibres. The program comprises special libraries where decimal numbers are represented with the highest accuracy (thousands of significant digits are needed). The recursive relationship analysis enabled to avoid repetition when calculating some of the terms, and thus accelerate the calculation process by a large number of orders of magnitude. The acquired data on the strength distribution function can thus be used to create an approximation of a precise distribution function, which, in the area of its mean, appears as a normal variable while its distribution tails represent a complicated development of the Weibull distribution with variable parameters. In 2015, two studies on this topic were published and what is more, an article (dealing with the same topic) will be published in a scientific journal in the near future.

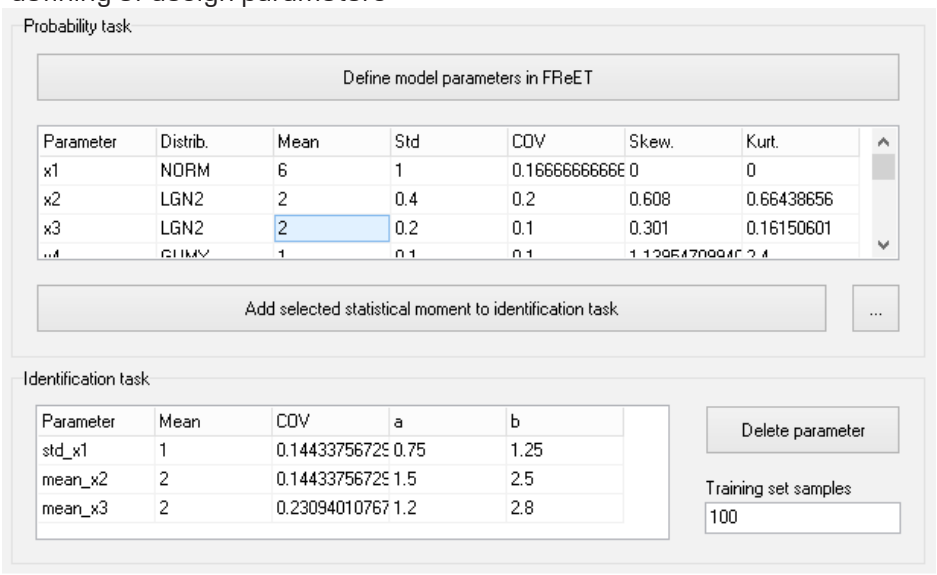
Another important research topic which we focused on in 2015 was the strength of composites reinforced with carbon fibre bundles. This type of reinforcement is used e. g. in the manufacture of textile concrete. Our research team succeeded in designing an advanced micromechanical model which is able to predict the gradual crack saturation of strained specimens and the related strength development as given by the changing tensile strain of the composites. Our studies on this model's behaviour then proved that weightrepresentation of fibres plays a major role in the process of tensile damage in quasi-ductile composites.

Our research activities also focused on the inverse problems of reliability and their solutions. It is a task which concerns determining of the so-called design parameters of a component / structure (material, geometric and load parameters or environment-related parameters) so that the required reliability level is ensured. Reliability levels are typically expressed by means of reliability indicators, such as reliability indexes and theoretical failure probability indexes. This must thus be handled as a typical inverse problem which cannot usually be analytically solved unless we use a deterministic system analysis (which can, however, only be applied to uncomplicated cases). In more complicated cases, a trial-and-error method is frequently used; first, an estimation of design parameters is carried out (mostly on the basis of predetermined empirical relationships or recommendations), and subsequently, the system's reliability is assessed. As regards a fully probabilistic solution of this task, searching for an analytical solution or using the trial-and-error method is at best rather time consuming and ineffective, and at worst completely impossible. Thus, it appears necessary to use one of the more advanced methods in order to find an inverse function.

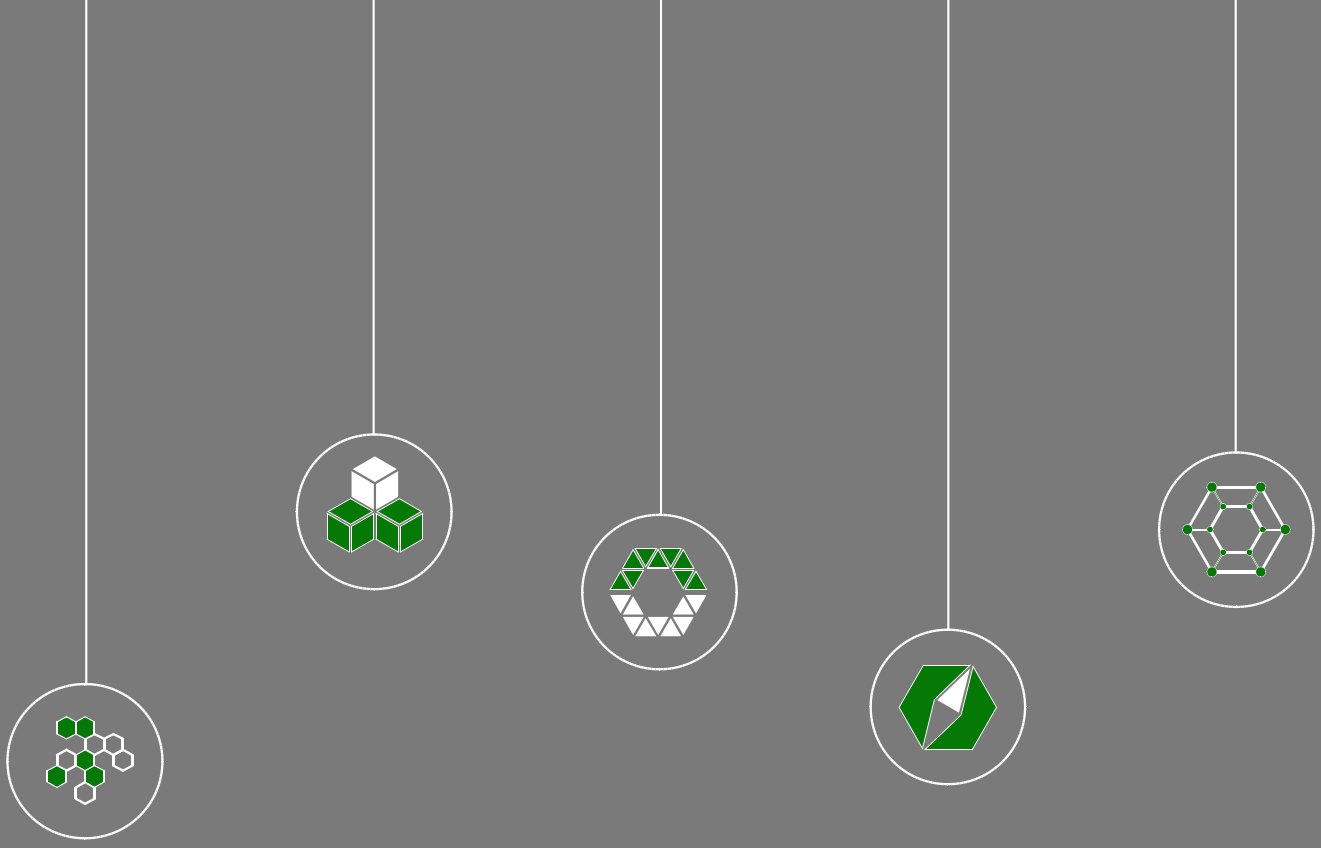
We came up with two different approaches to solving the inverse reliability analysis. The first one is a method based on combining artificial neural network with the stratified simulation method of Latin hypercube sampling, and the other is the so-called double-loop reliability optimization method. Both of the mentioned methods were developed with emphasis on the effectiveness of the solution, especially in terms of duration of the conducted nonlinear stochastic analyses. Both methods were used to identify the design parameters of several (theoretical and practical) civil engineering tasks. The practical tasks included designing of a cantilever beam's dimensions, a thickness and reinforcement design of a reinforced-concrete ceiling slab, a design of a steel beam's screw connection, and - in case of a segmental reinforced-concrete bridge – establishing of required load-carrying capacity of concrete in transverse joints and prestress losses. All of this was done with regard to the required reliability level as prescribed by the norms. Selected results of these solutions were published and presented at Civil Soft Comp, a renowned international conference. Besides, we have prepared an extended version of an article which is currently being reviewed in an Elsevier scientific journal.

As a part of the above described solution, we also developed the IReL (Inverse Reliability) software. It was developed in the object-oriented programming language Delphi and it is intended as an automation tool to deal with time-consuming task solutions which relate to the inverse reliability analysis using the artificial-neural-network-based method. The whole solution process requires direct communication between the reliability module and the module which is able to work with artificial neural networks. This communication is controlled by the above mentioned software. As a reliability module, we use FReET, a special program for performing statistical as well as sensitivity and reliability analyses (developed on our premises). For working with artificial neural networks, some of the available programs (e. g. the DLNNET software, which is also developed on our premises) can be used.

Fig. No. 23
The IRel program – defining of design parameters



Finally, we explored the possibilities of replacing traditional statistical methods with existing neurocomputing procedures and tools in sensitivity analyses. The neurocomputing tools are based on the so-called neural network ensemble (NNE) where the individual networks are trained on the same data sets, independently of one another. One of the advantages of the NNE approach is the improvement of general properties of the alternative model in comparison with a single independent network, which may prove to be a bit unstable. This is due to the fact that its input parameters (e. g. number of layers or neurons, random initialization of weights and threshold values etc.) tend to be rather indefinite. This lack of stability can, subsequently, negatively impact the accuracy of sensitivity coefficients.



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612 00 Brno
Czech Republic

www.admas.eu
admas@fce.vutbr.cz
phone no.: +420 541 148 011
GPS 49°14'07.5"N 16°34'19.4"E