Knowledge That Leaves a Mark

Knowledge That Leaves a Mark

SEVENTY-FIVE YEARS
OF THE SLOVENIAN NATIONAL BUILDING
AND CIVIL ENGINEERING INSTITUTE
1949–2024

Knowledge That Leaves a Mark

Seventy-five Years of the Slovenian National Building and Civil Engineering Institute 1949–2024

Editors: doc. dr. Aleš Žnidarič, Ema Kemperle, dr. Maja Kreslin, mag. Nina Gartner, Metka Ljubešek, Tamara Želimorski

Photographs: ZAG archive

Proofreader: Catherine Earles

Original title: Znanje, ki pušča sled

Published by: Slovenian National Building and Civil Engineering Institute
Ljubljana, October 2024

Design, layout: Birografika BORI, d. o. o.

First electronic edition
URL: http://www.zag.si/dl/ZAG-bulletin-2024.pdf

Also published as a printed publication.

ISBN 978-961-7125-12-2 (PDF)

Kataložni zapis o publikaciji (CIP) pripravili v Narodni in univerzitetni knjižnici v Ljubljani
COBISS.SI-ID 213793027
ISBN 978-961-7125-12-2 (PDF)

Contents

Contents

THE SLOVENIAN NATIONAL BUILDING AND CIVIL ENGINEERING INSTITUTE IN 2024

The beginnings of the Slovenian National Building and Civil Engineering Institute (ZAG) date back to 1949, when the then People's Republic of Slovenia established the Building and Civil Engineering Institute of Slovenia. In 1952, it was renamed the Institute for Testing and Research in Materials and Structures (ZRMK), which was then divided into a public part and a private part in 1994. The laboratories and most of the research activities were transferred to the public research institute. One of the fundamental goals of the new Slovenian National Building and Civil Engineering Institute was to continue the tradition of research and professional work upheld by ZRMK, which had been the central construction institute in Slovenia at the time. After three decades, it is clear that ZAG has successfully followed the path set, as we are now recognised both at home and abroad and are entirely comparable to the best related institutes in the countries of the European Union.

ZAG has been developing successfully throughout, the key having been the integration of research and professional work. Investing in new content, close cooperation with domestic and foreign industries, and the successful acquisition of research projects has paid off. Over the past five years, progress gained additional momentum as a result of the new Scientific Research and Innovation Activity Act (ZZrID), which gave greater autonomy to public research institutes and significantly accelerated investment in research and development, with progress further spurred by high economic growth – also in the construction industry, as one of the key economic sectors. Construction in the European Union generates approximately 6.2% of the gross domestic product, with related activities contributing considerably more. In Slovenia, the share of construction has also increased significantly in recent years – reaching 7.5% in 2023, which is the third-highest share across EU countries.

Activities

ZAG carries most of its work as research and professional activities, which, in recent years, have been represented in roughly equal proportions.

In 2023, we renewed the strategy of our operation, including our vision and mission. We defined five areas of our operation, which we implement in the context of research and professional activities:

1. The sustainable use of resources in the construction industry
2. Energy efficiency of the built environment
3. The safety, resilience and adaptability of the built environment
4. A healthy living/ built environment
5. New test methods and digitalisation in the construction industry

We pay special attention to facilities with special requirements, such as infrastructure relating to transport and energy, landfills - including those for radioactive waste - and cultural heritage. We increasingly devote ourselves to digitisation, without which development of the wider construction field is no longer possible.

Scientific research activity

Scientific research and development activity is a key component of our operation. We maintain direct contact with the latest scientific findings in many areas, which we publish in the most important international journals. Most of the research is part of international projects financed through various Horizon mechanisms, which proves that they are important for the development of science in a broader sense.
We are currently either leading or involved in 105 research projects, a good half of which are international. At a national level, we conduct the research programs Building Structures and Materials and Forest-wood Value Chain and Climate Change: Transition to Circular Bioeconomy, supported by the infrastructure program Testing of Materials and Structures.

The Horizon ERA Chair project FRISSBE, concerned with a fire-safe sustainable built environment, is one of the few successful European ERA Chair projects in Slovenia and is of key status for ZAG. In addition to the internationalisation of the Institute's operations, resulting from the large share of new colleagues from abroad, thanks to the FRISSBE project we have modernised a large part of the business, which has had a positive knock-on effect on our many daily activities. We were also partners in the Center of Excellence InnoRenew, the first European *Teaming* project won by Slovenia which was coordinated by the University of Primorska.

Both the scientific research activity and the general operation of ZAG were greatly influenced by ZZrID, which enabled many positive changes. We have increased the number of young researchers fourfold. Within the framework of the development pillar, we encourage the international exchange of researchers. Each year, we prepare tenders for internal breakthrough projects, through which we train younger colleagues to manage research projects. We also conduct numerous courses for researchers and support staff, which strengthens the competencies of our staff in various fields and significantly contributes to the excellence of ZAG's scientific research activities.

In addition to constant research and development in traditional construction areas, such as materials, geotechnics, structures and building physics, we have also significantly expanded into new areas of operation. We began to deal more comprehensively with cultural heritage, as part of which we joined the European network E-RIHS (European Research Infrastructure for Heritage Science) and became more closely connected with complementary institutions. The field of circular economy has developed intensively and has successfully obtained many research projects, including through EIT RawMaterials. In the field of microtomography, we have strengthened the team with internationally established researchers and purchased the largest and most modern microCT instrument in Slovenia. We have made substantial progress in the field of digitisation and digital production, through the development of materials for 3D printing of building elements as well as methods for scanning and digitally inspecting structures using drones. Following the opening of a new laboratory and the start of the FRISSBE project, the Fire Research and Engineering department was rewarded with a new impetus and international recognition. New areas have also been introduced, including the fire resistance of batteries, photo voltaic panels for solar power plants and larger facade elements.

In highly-specialised fields, we successfully cooperate with other research institutions, including the Universities of Ljubljana, Maribor and Koper, the Geological Survey Institute of Slovenia, the Institute for Metal Materials and Technologies, the Institute for the Protection of Cultural Heritage of Slovenia, the Center of Excellence InnoRenew, the Chemical Institute of Slovenia and the Jožef Stefan Institute.

We have taken a big step forward in increasing the recognition of our work. In addition to organising events, including workshops, summer schools, and Open Days, we have strengthened the public relations department, which has increased our visibility and led to our achievements being presented in the media several times.

A more detailed description of each of our research activities is given below.

Professional activities

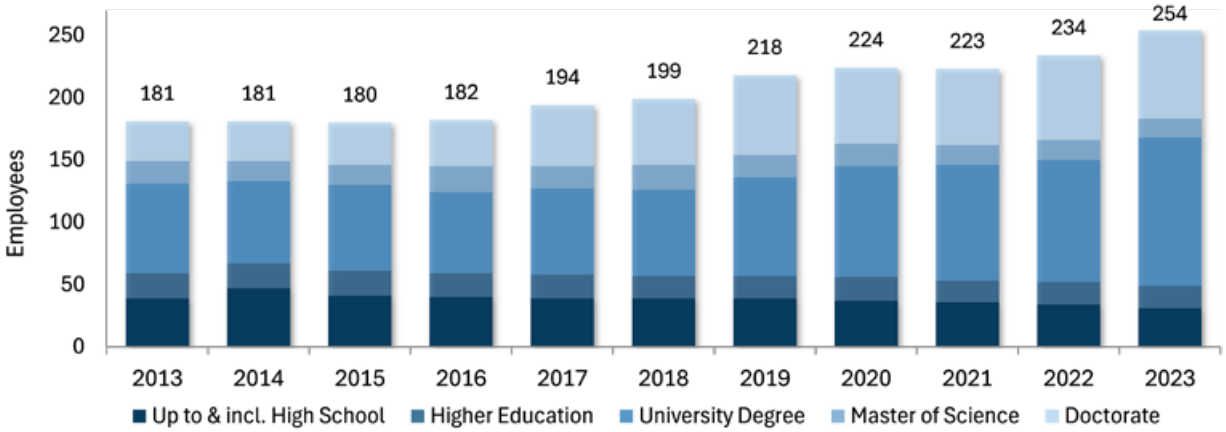
Another key area of activity in the Institute is professional activities. In the broader field of construction, we carry out tests and prepare technical opinions and analyses, studies, investigations, measurements, controls, observations and detailed inspections, supported by investigations and analyses regarding the condition of buildings, transport devices and transport infrastructure. We certify construction products, issue Slovenian and European technical assessments and approvals and environmental product declarations, and calibrate measures of force, torque, pressure, hardness, impact energy, length and temperature. We also perform external controls as an independent third party for the most important national infrastructure projects, such as the construction and renovation of road and railway networks and energy infrastructure. In 2024, we took over leadership of the Strategic Development Industrial Partnership (SRIP), 'Smart Buildings and Home including Wood Chain'. Professional activities are primarily based on, and influenced by, the results of our scientific research.

We actively participate in various bodies and often represent the country of Slovenia at the European level. Our expertise, breadth of knowledge, and the fact that we hold the largest number of accredited methods in the construction field across Slovenia should be our competitive advantage. Still, for most projects, we must compete in public tenders with other providers. Unfortunately, tenders often contain insufficient technical requirements, even in areas where we develop internationally comparable methodologies, technologies and investigation procedures. Despite the legally foreseen green orders, the lowest price, rather than the quality of the service, remains the key criterion for choosing a service, although this leads to significantly higher construction and management costs over the lifetime of a product. Unfortunately, such practice also slows the speed at which results from research are implemented into practice and consequently hinders the technological progress of Slovenia.

Employees

Like the rest of Slovenia and across the developed world, we face challenges in the employment field. Due to the critical lack of technical personnel with higher education in the labour market, retirements, and lower salaries in the public sector, it is difficult to compete with the private sector. Nevertheless, the number of employees reached 254 at the end of 2023, with the proportion of employees with a university education being 80%. In the field of research, the main reason for the growth in staff numbers was greater success in obtaining international and domestic research projects. As a result, we increased the number of employees with doctorates to 71. In marketing activities, we strengthened the external control activities for state clients, increased the number of technical assessments and approvals and environmental product declarations and certificates, and opened up new areas of research.

ZAG is committed to the principles of social responsibility, which are deeply rooted in our operations and policies and reflected in the advanced Socially Responsible Employer certificate we obtained in 2024. In addition to the positive ethics of our business practices, our integration into the community, our care for the environment and innovations for the social good, we have primarily committed ourselves to the well-being of our employees. We actively strive for their health, safety and professional development. As a result, we constantly improve the working environment to encourage personal and professional growth and to ensure all employees are valued and respected. We have significantly increased the number of various training courses for employees and facilitated more flexible working hours, with a greater share of work now being done from home. We have also established the Youth Council, through which younger employees, who are not in managerial positions, develop their views and present them to ZAG's management.



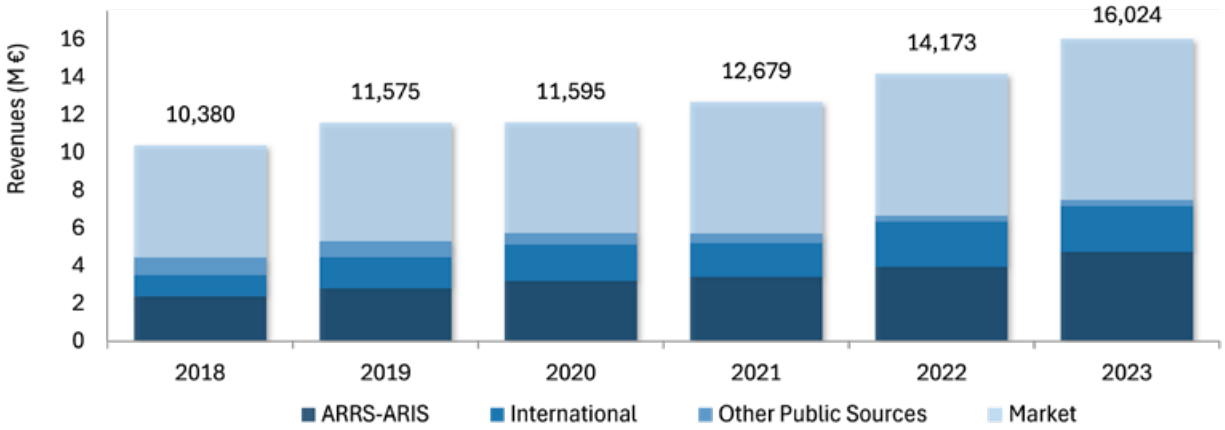
Graph 1: Number of ZAG employees by level of education

Business

The Institute has operated successfully throughout its history. We cooperate with many partners, with more and more of them now coming from abroad. The most important partners represent the state. As a public research institute, we get just under a quarter of our income from stable funding. The other three-quarters of the revenue is obtained from the market. About a quarter of the total is from research, development and other projects financed by various European mechanisms and the Public Agency for Research and Innovation of the Republic of Slovenia (ARIS). A large number of the remaining market projects are obtained through tenders from state clients, such as the Motorways Company of the Republic of Slovenia, the Directorate of Infrastructure of the Republic of Slovenia, the Slovenian Railways, 2TDK and the Agency for the Management of Radioactive Waste. For these projects we carry out the quality control of works and conduct main and detailed inspections for key transport and energy infrastructure. We cooperate with many other partners on concrete projects and within the Strategic Development Industrial Partnerships framework.

We are intensely involved in international cooperation. I highlight our cooperation in FEHRL (the Forum of European Highway Research Laboratories), ENBRI (the Association of European Network of Building Research Institutes) and EOTA (the European Organization for Technical Approvals). In 2022, we joined the European Research Infrastructure for Heritage Science (E-RIHS). We are active in the European technology platforms for construction, the built environment and energy-efficient buildings (ECTP) and road transport, (ERTRAC), as well as the Knowledge and Innovation Center EIT RawMaterials. In each of these organisations, our representatives work in management bodies. We actively participate in international workshops, conferences, congresses, associations and committees. Without this kind of active cooperation, fewer research projects would be obtained, and, as a result, there would be less exchange of knowledge and reduced progress.

The result of the activities listed above is stable business, with growth that slowed down only in the first year of the COVID epidemic, which significantly impacted ZAG's market revenues.



Graph 2: ZAG revenue streams

Infrastructure

Over the last five years, excluding the investment in the new fire laboratory in Logatec, we have spent EUR 4.5 million – equating to 6.7% of our operating income – to purchase and modernise research and testing equipment and infrastructure. About a third of this was financed by ARIS and the Ministry of Higher Education, Science and Innovation (MVZI). As a result, we now have modern laboratories and testing equipment, enabling employees to carry out high-quality research and marketing activities.

During this period of investment, we completed several important projects. In 2021, we opened a new business unit in Maribor. The residential premises where the previous unit had operated since 1972 had long ceased to be suitable. Our new modern premises with laboratories in Dobrovci, near Maribor, will enable further expansion and allow us to strengthen our presence in the eastern cohesion region.

In 2022 we opened one of Europe's most modern fire laboratories in Logatec. MVZI provided almost half the funds for the construction of the building, while part of the equipment costs were funded by the InnoRenew operation through European cohesion funds. The remainder of the funds were covered by our operating surpluses from previous years. The new premises enable the research and testing activities of the fire engineering department to expand into new areas. The fire laboratory in Logatec is also home to the ERA Chair project FRISSBE, which significantly increases ZAG's visibility in the international environment.

After resolving the ownership issues at our headquarters in Ljubljana, we converted several previously abandoned premises into laboratories and accompanying facilities. We have regularly renovated the offices and other laboratories. In 2022, with the help of national investment funds from MVZI, we bought the last facility we did not own - the concrete laboratory. Renovation of this laboratory and relocating from the current premises will boost development in the field of one of the fundamental building materials.

Finally, over the past five years, we have bought some important research equipment, either fully funded by ourselves or with co-financing from the ARIS. These include the largest microCT in Slovenia, a robotic arm for 3D printing, furnaces and cleaning equipment in the fire laboratory, a modern laser scanner, and drones. We have also procured several pieces of equipment in cooperation with other JRZs.

Conclusions

The Slovenian National Building and Civil Engineering Institute has developed and operated successfully over the past five years. We are proud that, according to the most important indicators, we remain comparable to the best related institutes in more developed European countries. This has only been possible with the outstanding commitment of all our employees, researchers, experts and support staff, to whom I would like to express my sincere gratitude.

The last decade has proven that knowledge and technological development are essential for the survival of individual parts of the economy and the overall well-being of citizens. In this sense, it is key that Slovenia has preserved most of its national research institutes – which, on the international stage, prove that we are comparable with the best. Transferring our results into practice is somewhat more difficult. I hope that new legislation, which puts a much greater emphasis on innovation, will accelerate progress in this direction. I also trust that most players in the construction field, rather than only exceptions, will realise that a successful future requires greater investment in research and development. With its highly qualified personnel and modern equipment, the Slovenian National Building and Civil Engineering Institute will certainly play its part in helping to move in this direction.

Ljubljana, 18/10/2024

Dr. Aleš Žnidarič, Director

Milestones
1949–2024

1949: The Government of the People's Republic of Slovenia establishes the Slovenian Construction Institute. Its primary activities are research, testing and development in construction and the construction materials industry.

1953: The Construction Institute is transformed into the Institute for Testing and Research in Materials and Structures (ZRMK).

1972: A unit is established in Maribor to carry out activities in the north-eastern region of Slovenia.

1984: A seven-storey facility is built with new laboratories and office space.

1986: The fire laboratory in Gameljne, near Ljubljana, starts to operate.

1991: ZRMK becomes a public institute in the new country of Slovenia.

1994: Part of ZRMK is restructured into a public research institute, the Building and Civil Engineering Institute – ZRMK, and becomes a member of the Forum of European National Highway Research Laboratories (FEHRL).

1996: The Building and Civil Engineering Institute – ZRMK is renamed the Slovenian National Building and Civil Engineering Institute (ZAG).

1999: Slovenian Accreditation (SA) and the Swedish Board for Accreditation and Conformity Assessment (SWEDAC) accredit the first eight laboratories. ZAG acquired the research programs Structural Engineering and Building Materials.

2000: ZAG becomes a member of ENBRI, the European Network of Building Research Institutes.

2003: ZAG becomes the Slovenian authority for technical assessment and represents the Republic of Slovenia in the European Organisation for Technical Assessment (EOTA).

2007: The Slovenian Institute of Quality and Metrology (SIQ) grant ZAG certification for a quality management system according to ISO 9001:2000. ZAG is one of the cofounders of the platform Energy efficient Buildings (E2B).

2008: In partnership with the companies DDC and DRC, ZAG organises the largest European conference in the field of road transport, the Transport Research Arena (TRA), in Ljubljana. The Metrology Institute of the Republic of Slovenia designate ZAG as the holder of the reference standard for the units of force, hardness and the quantity of matter for cement. The Director of ZAG, Dr. Andraž Legat, becomes vice president of the association FEHRL.

2009: ARRS grants ZAG funding for the infrastructure program ‘Testing of Materials and Construction’. ZAG director Dr. Andraž Legat is appointed president of the European association ENBRI.

2011: ZAG takes over management of the TIGR Competence Centre for Sustainable and Innovative Construction.

2012: The Ministry of Economic Development and Technology designate ZAG as an authority for technical assessment. The Slovenian Environment Agency accredit ZAG as a body for noise assessment using calculations/ modeling.

2013: The Ministry of Agriculture and the Environment designate ZAG as an authorized expert for radiation and nuclear safety. The Ministry of Infrastructure and Spatial Planning authorise ZAG to issue energy performance certificates. ZAG fulfils the scope of activities as a notified body in accordance with the Construction Products Regulation.

2014: The Ministry of Infrastructure and Spatial Planning authorize ZAG to carry out professional and technical inspections of cableway installations.

2015: ZAG becomes a member of the association EIT RawMaterials e.V. (EIT RM) and obtains funding for the first projects.

2016: An extension to the Laboratory for Structures is built with European funding. As part of the Teaming project, ZAG is a cofounder of the Centre of Excellence for research and innovation in the field of renewable materials and a healthy living environment (InnoRenew CoE).

2017: ZAG is a cofounder of four strategic development-innovation partnerships (SRIPs).

2021: ZAG opens a new business unit in Dobrovci. ZAG acquires the FRISSBE ERA Chair project.

2022: ZAG opens the largest and most modern fire laboratory in this part of Europe in Logatec, built using European, Slovenian, and ZAG’s own funds.

2023: The Director of ZAG, Dr. Aleš Žnidarič, becomes president of the association FEHRL.

2024: ZAG becomes an associate partner within the inter-university program, »International Master of Science in Fire Safety Engineering« (IMFSE). ZAG assumes leadership of the SRIP, ‘Smart Buildings and Home including Wood Chain’ (PsiDL)

Directors
Through History

Marjan Ferjan	1949–1951 (Director of the Institute)
prof. **Viktor Turnšek**	1951–1954 (Director of the Institute), 1954–1975 (Director of ZRMK)
Franc Čačovič	1976–1980 (Director of ZRMK)
prof. dr. **Jože Vižintin**	1980–1986 (Director of ZRMK)
Borut Gostič	1986–1992 (Director of ZRMK)
prof. dr. **Roko Žarnić**	1992–1993 (Acting Director of ZRMK)
mag. **Damijana Dimic**	1993–1995 (Acting Director of the IRPK OU), 1995–1996 (Acting Director of the BCV Institute – ZRMK)
akad. prof. dr. **Miha Tomaževič**	1996–2005 (Director of ZAG Ljubljana)
izr. prof. dr. **Andraž Legat**	2005–2019 (Director of ZAG Ljubljana)


PROF
VIKTOR
TURNŠEK
1911 – 1981

In 2024, in addition to the 75th anniversary of ZAG, we also commemorate the 200th anniversary of Aspdin's patent of Portland cement - a material that caused a revolution in construction and still dominates as a construction material today. Associated with the intriguing combination of cement's and ZAG's anniversaries, a now petite lady with fiery hair comes to mind for many of ZAG employees. In her achievements, she is anything but petite; in her old age she remains very sharp-minded and has a good memory, is evasive, critical, pervasive, curious, and a sovereign expert. She is the leading author of an article in the famous scientific journal, Cement and Concrete Research, the author of two independent chapters in the RILEM report, 'Application of admixtures in concrete: state-of-the-art report', and the author of more than fifty studies, reports on the results of investigations.

Some words about her, cement and ZAG.

"When I came to work for ZRMK, my boss, the late engineer mag. Stane Droljc, put a research proposal on my desk that had been sent to Belgrade: 'The development of expansive cement'. This was my first assignment. I had no idea about cement whatsoever."

Mag. Damijana Dimic,

chemist, long-time head of the cement laboratory at the Institute for Research of Materials and Structures (ZRMK), was the only woman to hold the director's position at the Institute. Since 1993, she led the organizational unit Institute for Research and Quality Assurance at ZRMK, and after the restructuring of ZRMK, she was the acting director of the newly established Construction Institute from 1995 to 1996.

I actually graduated in polymers, but there were no jobs at the time, and I waited three or four months to get a job. I had a lot of success with expansive cement. My boss, engineer mag. Stane Droljc, and I even received an award from the Kidrič Fund for the development of this material. It was used in hydroelectric power plants, you know."

The Boris Kidrič Fund Award was awarded to the researchers and developers mag. Stane Droljc and mag. Damijana Dimic in 1984. It was an award for important scientific works that had been published in the previous year and was split into four categories: natural and mathematical sciences, technical sciences, biotechnical and medical sciences, and social and humanistic sciences. Droljc and Dimic received the award for their research work investigating the synthesis and characterization of calcium sulfoaluminates as the basic mineral component of expansive and non-shrinking cements, as well as for research into the hydration processes. The justification for the award was that the merit of the work was original reasoning, with thoroughly designed experiments, through which the authors explained the reaction mechanism and established data that had not yet

been published in the literature. The authors presented their work at the 7th International Congress of Cement Chemistry (ICCC) in Paris in 1980, in five papers on research work over the years 1978-1983, and in six public publications. The special merit of the authors was that they put the results of their research work into practice: a device for the annual production of 2,000 tons of non-shrinkable and expansive cements was under construction, and they also introduced the use of these cements for construction of the hydropower plant (HPP) Solkan on the Soča river and the use of non-shrinkable cements of other types in the construction of HPP Zlatoličje and HPP Vuhred on the Drava river.

"The big problem in concrete has always been concrete shrinkage – although this is less apparent today because materials have already been developed to prevent it. At ZRMK, we developed expansive cement for hydropower plants, and we developed an expansive additive for pretensioned cables, known as Ikaton. This one really paid off, because at that time the cables were not yet so well protected. The need for protection was not noticed back then either, because the roads were not salted as much, and there was also less prestressed concrete. The first structure on which the application of Ikaton was implemented was the Verd viaduct. The contractor was Mostogradnja from Belgrade, and our technical director, Slovenian, engineer Marjan Ferjan, knew their director. He hinted to Ferjan that they needed such an additive - and we developed it, and we succeeded. It was quite a successful project. After this, it was expansive cement's turn …"

At that time, the Institute's activities were predominantly market-based, and research activities were financed by the state, through project applications. Due to the requirements of Europe, the activities of the Institute had to be redirected and the production activity abandoned.

"The Institute then became a national institute, and it was necessary to adjust its status so that it was independent. We weren't independent at the time because we had semi-industrial production and renovations, which saved us in the previous regime, where we were not funded by the state but through market activity. The research was financed by the Federal Fund for Scientific Research in Belgrade, so we sent our proposals for research there, and I must say that our institute was very well known in Yugoslavia - ZRMK was also the first institute to be established in Yugoslavia. The Ruđer Bošković Institute in Zagreb and the Institute of Civil Engineering in Belgrade were also very good. Later, smaller institutes were also established, in Banja Luka and Skopje, I think. We did quite a lot of research that was paid for, and the rest we earned on the market. It was primarily research for development, less basic scientific research."

With involvement in the market, it was easier to determine the direction of research and development - the needs were clear.

"We were the ones identifying the needs and proposing topics. The construction industry itself did not recognize the needs, especially not the construction materials industry. This is because, at that time, there were so few building materials on the market that they did not feel the need to develop new ones. That's how we imposed the trend. We produced a lot of products and semi-finished products in Gameljne, and this brought us a lot of finance, as since we knew the market, and what the industry needed, we always found a product. At that time, imports were very problematic - in fact, there were no imports at all. The management, who were more familiar with the trends and needs of the construction industry, gave us hints as to what needed to be researched and developed. And that's how we developed. There was a lot of development in the construction of highways and hydropower plants."

Despite the closed borders, the equipment in the laboratories was good.

We had our own workshops. At that time, the problem was the import of equipment through closed borders. We had a mechanical workshop and a carpentry workshop, and they did everything for us. When we said we would like to measure the expansion of the grout for the pre-stressing cables, they did a little digging in the literature – which, of course, we had - and they designed and made the measuring set. We even had a glass blower. When the two institutes were separated, all of that ended with the justification that it is no longer profitable. Today, it is easier to get equipment, there are more funds, but I think that development and the laboratory still need this kind of support. You can't buy every glass flask on the market. It is better if you can go to the workshop and say what exactly you need, and they blow it for you."

Successful innovation and development were replaced by standards, and a civil engineer stepped into the shoes of a chemist ... well, heels, actually ...

Later on, we had to abandon market production because that part was assigned to another institution. We were more concerned with what Europe demanded - with new standards. I must say that within this framework we travelled a lot - or at least I, personally, did. We attended CEN meetings, where we started as observers, because we were not yet members, then later we were allowed to participate in standardization. This is how we came to the new directive on construction products, which I translated, and that was a bit blasphemous. At that time, the Slovenian Institute for Standardization felt they were an authority in this field. My translation was primarily intended as preparation for the changes to come - because these were significant changes. In 1995, the two institutes (ZAG and ZRMK AN) finally separated. I was the acting director for so long that we adopted all the statutes and regulations. We had to fight for salaries because they were dictated by the ministry. Suddenly, the salaries were lower than before. Half a year later, a call for the director was announced, but I was about to retire, and I said that a candidacy from me would not make any sense. It was better for me to help someone else get started on the job. My offer was then accepted by dr. Miha Tomaževič."

Her story with cement and ZAG did not start after graduating from college, but a little earlier:

I was on an internship at ZRMK in my third year of study. At the Laboratory for Cement to be precise. And I felt good there. Wonderful people."

The positive atmosphere during her time at the Institute cannot be overlooked, as it emanates from her words. She also comments on faster job changes being a feature of modernity.

I think that things used to be a little different back then. As employees, we felt a greater sense of belonging to the institution, to the company where you went to earn your living. There wasn't that much staff turnover. Colleagues of mine were younger, because the institute was also young and it was nice to work with them, we were a really nice team. The situation changed in that, the demands of Europe ... everything fell apart. In its best years, as many as 800 people were employed at the Institute. Then the number dropped because there wasn't as much business."

She cannot, and does not, hide her devotion to the Institute.

ZRMK was actually my life. Everything happened there. I never thought about doing anything else",

says Dimic, with sparkles in her eyes. Perhaps these sparks promise to ignite the next 75 years of ZAG and another 200 years of cement. If not more.

Ana Brunčič

Research and Development for a Sustainable Built Environment

As a credible partner, we create and transfer cutting-edge knowledge for the development of a sustainable built environment.

The Slovenian National Building and Civil Engineering Institute is a public research institute whose fundamental activity is scientific research. In recent years, our multidisciplinary perspective has been replaced by a transdisciplinary approach, with researchers combining knowledge from various fields to surpass the boundaries of individual disciplines. Quality research work, the ability to connect different disciplines, and the integration of fundamental and applied research to address real-world challenges all contribute to the growing recognition of the Institute.

The scientific research vision of the Slovenian National Building and Civil Engineering Institute

In 2022, the Institute's scientific council formed a new vision for the scientific research activities of ZAG for the period up to 2027, including the mission and priority areas of knowledge development and research, which states:

- We will be recognised for our scientific excellence in Slovenia and beyond
- We will be a valued partner in research projects
- We will present at prestigious conferences and be part of reputable professional associations
- We will actively particpate in the development of national and international policies
- We will successfully transfer our knowlege to the economy
- We will cultivate knowledge inclusively, through interdisciplinarity and mutual collaboration.

In fulfilling our scientific research mission we are guided by the values of reliability, cooperation, superior knowledge, mutual respect, usability, sustainable development, learning, independence, ethics, interdisciplinarity, self-initiative, responsibility and honesty.

As part of its renewed strategy, the Institute has identified five priority research areas:

01

Sustainable use of resources in construction: this area focuses on innovative principles of circular construction, promoting material efficiency, waste evaluation, industrial symbiosis, cascade recycling, the replacement of critical and hazardous substances, the sustainable use of natural materials, the digitalization of value chains and the development of circular business models to shape the future of construction.

02

Energy efficiency of the built environment in the construction sector: research in this field aims to efficiently manage energy in the built environment. Collaborating with partners, the Institute develops innovative solutions for utilizing and managing renewable energy sources, thereby contributing to a sustainable future.

03

Safety, resilience and adaptability of the built environment: the Institute explores new ways to ensure the mechanical and fire resistance of buildings and transportation infrastructure. Solutions are designed to prevent damage from constant and frequent influences such as weight, earth pressures, traffic and wind, as well as to enhance safety during exceptional events like earthquakes, fires, landslides, storms, and floods. Adaptation to climate change and urban mobility requirements are also considered.

04

Healthy living/ built environment: to create conditions for healthy living environments, key environmental components - such as air quality, water, noise, heat, humidity, vibrations and ergonomics - need to be addressed. The Institute investigates and discovers new approaches to removing harmful factors from the environment.

05

New test methods and digitisation in construction: research in this area focuses on the development and implementation of novel testing methods, observational techniques for construction objects and infrastructure and analytical tools that can be used to leverage new information and communication technologies.

The priority areas of research outlined above are the pillars of our research work, their interconnection, and the research freedom afforded to our researchers. These open up new research questions and challenges, allowing us to build a safer and more sustainable society through the development of new methods and technologies and by observing the sociological aspects of living. While individual research areas yield exceptional scientific results, highlighting ZAG as a key partner for research, other areas excel in applied outcomes, making ZAG an important collaborator for industry engagement.

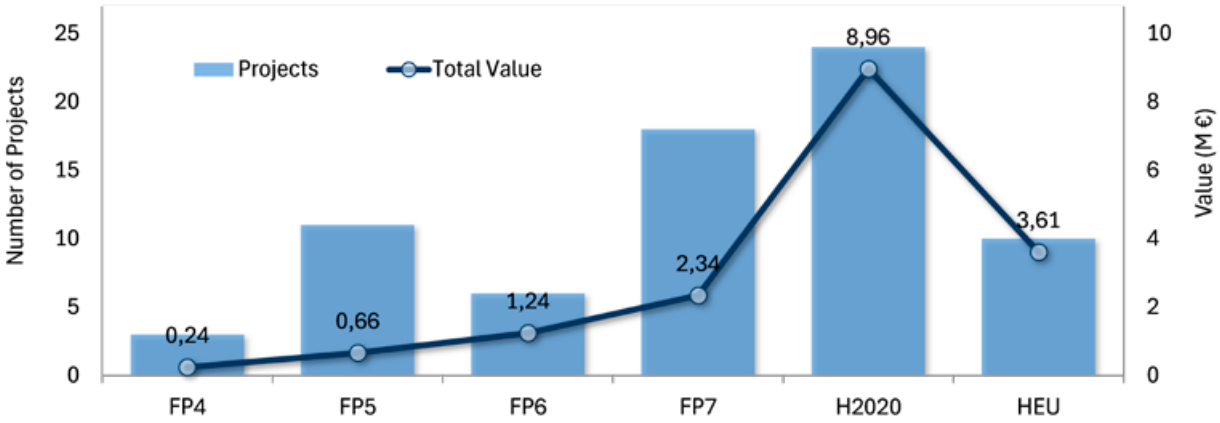
Research projects

Slovenia has been involved in European Union research and innovation framework programs since the third framework program (FP3) ran between 1990 and 1994. The first projects by ZAG were carried out under the fourth framework program (FP4), following several COST actions. Since then, funding for research and innovation has steadily increased. We are currently in the midst of the ninth framework program (Horizon Europe), by the end of which we expect revenue to have exceeded €9 million. An overview of the number of projects and funding acquired through the European Union's research and innovation framework programs is given in Graph 1.

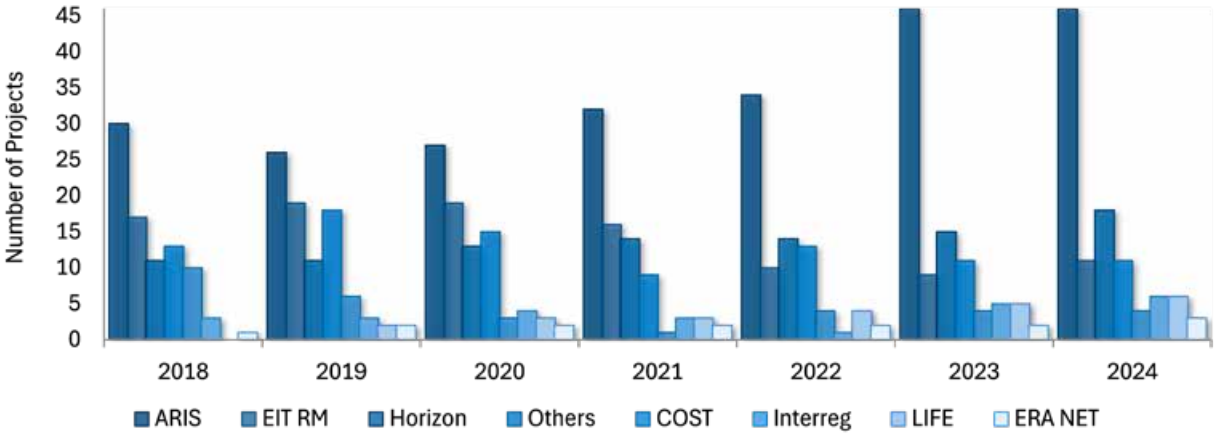
In addition to projects in the framework program, staff at ZAG are involved in research projects funded by other sources. At the time of writing, in the first half of 2024, 105 projects are currently underway, with at least 10 additional projects expected by the year-end. Over the past five years, the number of projects has increased by more than 20%. The success of ZAG researchers is evident not only in the projects obtained from new programs but also by the fact that we have secured coordinating roles in significant initiatives. The distribution of projects by funding program and year is illustrated in Graph 2.

Despite the increasing number of projects, it is positive that the proportion of domestic or international projects never exceeds 60%. This balanced approach ensures sustainable development and provides more stable research funding, even during periods when framework programs and strategies change.

Among the international projects currently underway at ZAG, we highlight the FRISSBE project (Fire-Safe



Graph 1: Number of research projects and funds obtained under the framework programs of the EU, source: Horizon Dashboard Country Profiles (source: https://ec.europa.eu/info/funding-tenders/opportunities/portal/screen/opportunities/horizon-dashboard, 29. 7. 2024)



Graph 2: Number of research projects by programs in the years 2018–2024

Sustainable Built Environment), which was selected for funding under the H2020 WIDESPREAD ERA Chair call. FRISSBE is one of the most successful ERA Chair projects in the region, employing 10 researchers, most of whom are foreign, and supporting the development of new scientists in the field of fire-safe sustainable built environments through visits from student researchers from around the world.

Research within ARIS funding

In 2022, a significant portion of the funds from the Slovenian Research and Innovation Agency (ARIS) transitioned to stable funding. On one hand, the autonomy gained through ZZrID has imposed great responsibility on the recipients, but on the other hand it also allows us the freedom to carry out important activities that were previously hindered.

ZAG conducts two research programs under stable funding: Building structures and materials (P2-0273) as an independent performer and Forest-wood value chain and climate change: transition to circular bioeconomy (P4-0430) as a partner, with the leading partner being the Slovenian Forestry Institute. Both research programs are supported by the infrastructure group Testing of Materials and Structures (I0-0032).

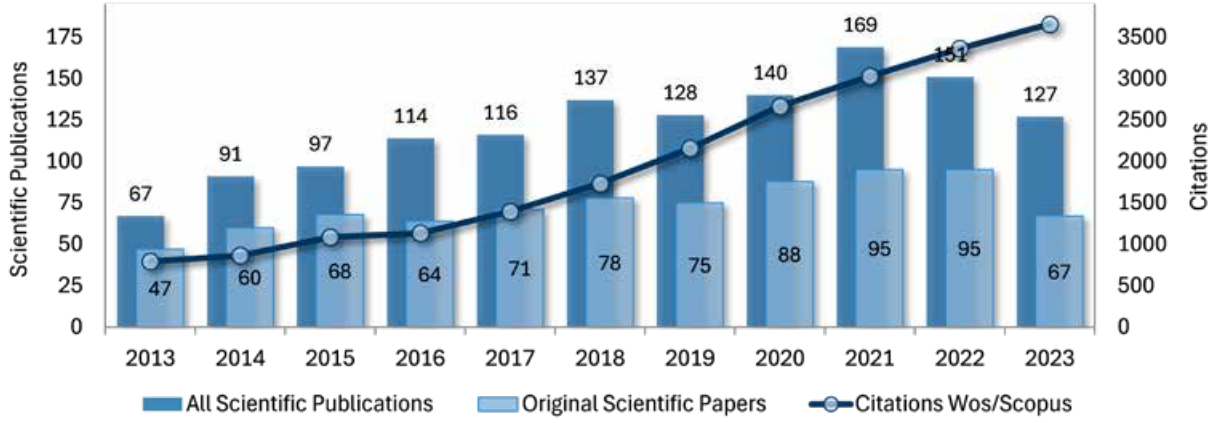
Within the research programs, activities are carried out in all the five strategic areas mentioned above, as well as in horizontal research activities such as built cultural heritage, additive technologies, digitalization and microtomography amongst others. In all research activity - both within strategic areas and in horizontal activities or other cross-sectional internal projects - the emphasis is on a scientific approach. The importance of our research results is evidenced by the number of publications and citations, which have significantly increased in recent years.

Graph 3 illustrates the number of scientific publications, the proportion of original scientific articles, and the number of citations between 2013 and 2023.

With stable funding, ZAG has significantly expanded its research activities, both in terms of the overall resources allocated and the proportion of labor costs within those resources. Since 2022, we have actively increased the number of young researchers, intentionally strengthening the strategic workforce necessary for us to continue our delivery of excellent scientific research.

Research program P2-0273: Building structures and materials

The research program 'Building structures and materials' serves as a central driver of scientific research at ZAG. It connects all five strategic research areas, all six scientific research departments, and various horizontal research groups. New research



Graph 3: Bibliographic indicators of research performance (source: COBISS.SI/COBIB.SI database, 10. 7. 2024).

domains often emerge from close collaboration between program members and their integration into both Slovenian and international research environments. By combining diverse groups of researchers, we achieve synergistic effects in specific, narrower fields. The importance and relevance of our research areas are confirmed by our numerous scientific publications and successful participation in international and national projects. ZAG researchers excel in various research and technological domains on a global scale. Thanks to the supportive environment provided by our infrastructure program and the collaborative staff in support services, we stay abreast of the latest global research. The freedom afforded by stable funding allows us to swiftly adapt our research to changing technological conditions and societal and environmental needs. Our transdisciplinary group of researchers ensures the necessary flexibility and a comprehensive approach to addressing challenges.

Research program P4-0430: Forest-wood value chain and climate change: transition to circular bioeconomy

The research program 'Forest-wood value chain and climate change: transition to circular bioeconomy' addresses current challenges within the forest-wood value chain (from standing trees to final products). It connects three research organizations: the Slovenian Forestry Institute, as the leading partner, and the Slovenian National Building and Civil Engineering Institute and the Biotechnical Faculty of the University of Ljubljana as co-executors. Researchers provide an interdisciplinary and innovative approach to achieving the goals set and connect

the group with the industry. The scientific research work focuses on finding optimal solutions based on our existing knowledge and available resources (laboratories and databases).

The Slovenian National Building and Civil Engineering Institute plays an important role in researching and developing an optimal process for the protection of non-biocidal wood, especially for domestic wood species, which can prevent biological decay without altering the positive properties of the wood. Additionally, we seek solutions to improve its fire resistance. We are also heavily involved in researching massive wooden structures made from glued wood, such as glued laminated timber (GLT) and cross-laminated timber (CLT), largely supported by the infrastructure program.

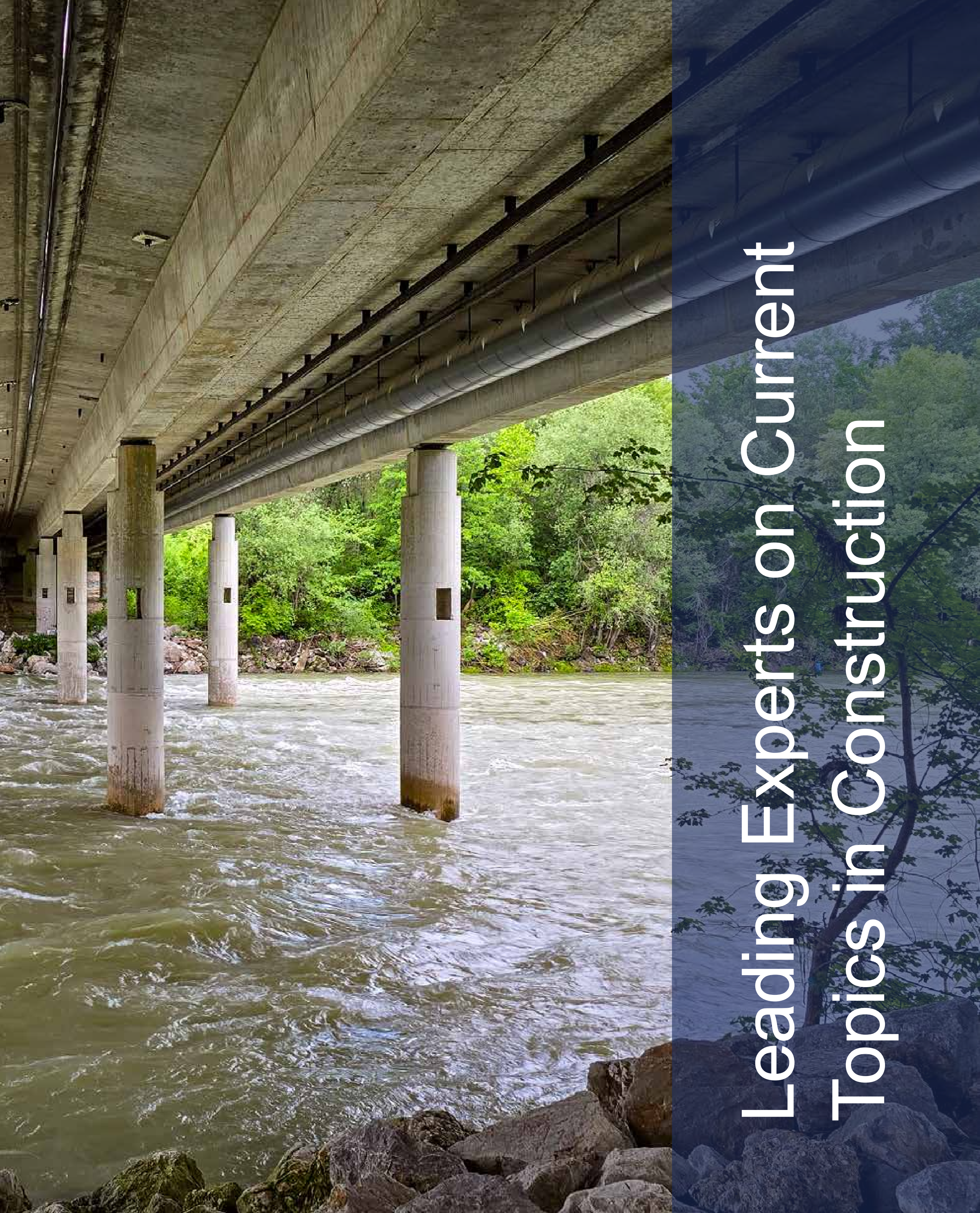
Infrastructure program I0-0032: Testing of materials and structures

This infrastructure program supports scientific research work, including research programs as well as Slovenian and international research projects. The activities of the research program encompass several specific goals, including maintaining and monitoring progress in research equipment, supporting programs, projects, state and government bodies, training staff, connecting to infrastructure networks and living laboratories, transferring knowledge and popularizing science. The support activities are distributed across departments, connected, and encouraged by the Project Support Service and the Public Relations Service, which ensure the establishment of a knowledge management system and organize Open Day events and other promotional activities.

International collaborations

Through its transdisciplinary work in various construction areas, and by connecting fundamental and applied research to address real-world problems, ZAG has become recognized both at home and abroad.

In terms of research activities, ZAG primarily collaborates with partners from European associations such as ENBRI (European Network of Building Research Institutes) and FEHRL (Forum of European National Highway Research Laboratories). Notably, ZAG's director is the current president of FEHRL, serving from 2023 to 2026. Additionally, ZAG's involvement in technological platforms like ECTP (European Construction Technology Platform), ERTRAC (European Road Transport Research Council), and E2BA (Energy Efficient Buildings) has been beneficial. Furthermore, as a partner in EIT KIC (European Institute of Technology, Knowledge and Innovation Centre) RawMaterials, ZAG strengthens its ties to the EU research landscape and collaborates with universities and industry partners. Overall, in terms of the key indicators (EU research integration, participation in technical committees and university-industry connections), ZAG's performance aligns well with other, similar research institutes across Europe.



Leading Experts on Current Topics in Construction

Advanced Materials in Construction

dr. Alenka Mauko Pranjić
Head of the Department of Materials

What activities is your department currently engaged in?

In the Department of Materials, we cover various materials and many topics in which ZAG's scientists and experts are top of their field, including products from secondary raw materials, new functional materials, the corrosion of metallic materials, additive technologies, environmental technologies, new cements and CO_2 capture in construction materials, and the pathology of materials. We work a lot on circular construction, with the aim of making research useful in practice, such that new products and technologies can be placed on the market. We undertake considerable activity in X-ray 3D imaging techniques, where ZAG, with its excellent team and equipment, is becoming more and more recognized, both in Slovenia and around Europe. This year, many activities took place in the field of cultural heritage – a topic that has always been present in the department but, in view of the research and professional needs in modern construction, has never been a central topic. Regardless, important developments were certainly seen in this area this year (e.g. the organization of an international summer school on the topic of non-destructive tools in cultural heritage, involvement in E-RIHS.si and the LINXS infrastructure networks, new research

projects and new publications). The pathology of building materials has also been a relevant topic for many years, both professionally and in the field of research, and in some areas we are the only ones who can give comprehensive answers to our clients in Slovenia as to why certain damage to construction materials and construction works has occurred. Some of the more recent topics we have been working on include, amongst others, the hydrogen embrittlement of steel, the photocatalytic conversion of solar energy into energy products such as hydrogen and methane and the simultaneous capture of CO_2, sensors based on mesoporous silica, the improvement of air quality through the conversion of volatile organic components via photocatalysis, and improving the durability and fire properties of wood through mineralization.

Which materials could reduce CO_2 emissions the most?

Apart from steel, cement and concrete contribute most to the high carbon footprint of the construction sector, so a lot of activity is being directed towards the development of new, more sustainable cements and concretes using supplementary cementitious materials based on recycled waste, alternative binders and mineral carbonation, whereby binders based on cement, ash or other additives in building composites bind CO_2. We are researching alternative primary (e.g. dolomites as a potential source of Mg-based cements) and secondary (various wastes such as Ca-rich ash) raw materials, and the mechanical-physical and chemical properties of new binders and composites, which must be evaluated in the context of their intended use (e.g. changes in strength and durability, binding mechanisms, risk of leaching potentially hazardous substances). For many years we have been working on geopolymers, or alkali-activated materials, which are a very good alternative to cement composites, but depending on the source used for activation, the risk of leaching must always be checked e.g. the leaching of heavy metals in an alkaline medium.

You participate in many research projects. Which would you highlight?

It is true, we participate in many international research innovation projects as an alternative funding for our research work - from those where we develop new construction materials and technologies (e.g. in programmes like Horizon, M-ERANET and ERAMIN), to those that are more applied or marketable, with a higher Technology Readiness Level (TRL), e.g. in programmes like EIT Raw Materials and LIFE. Some of our projects are aimed at the development of innovation ecosystems and proposals for improving regulation and legislation or education and capacity building (e.g. cross-border projects, regional Interreg programmes, EIT RawMaterials educational programmes and integrated LIFE programmes). The topics relate to recycling, circular construction and sustainability, additive technologies, the promotion and design of programmes for lifelong education and academic education on new topics that are not yet included in conventional education systems, the field of new functional materials and technologies, and materials in highly demanding environments. We are currently contributing in the development of new materials and technologies for storing energy, hydrogen and other energy products. In short, we are involved in the entire construction value chain, and we aim to connect the stakeholders of the innovative ecosystem built by research institutes, industry, educational institutions, decision-makers and the general public. Regarding the latter, I must highlight some projects where citizens also have a great influence on research, i.e. citizen science, such as involving cyclists in the dynamic monitoring of air quality, for example, or citizens collecting data on the quality of drinking water.

How does artificial intelligence or digitization affect your work?

This is an area that cannot be neglected, either in research methods, in the design and development of new materials and technologies, or in decision-making. Digitization and artificial intelligence are now part of our everyday, be it an advanced technique for the reconstruction of X-ray tomographic images or the development of digital passports or online marketing material. There are many challenges for us in this field, including employing suitable personnel to work on digital topics and materials.-

What improvements to materials do you think would most increase the resistance of construction works to flooding?

We were not very involved with flooding in our department last year, perhaps only with the problem concerning the spread of various pollutants in individual areas of flooding, and the generation of large quantities of potential construction materials, e.g. rocks, gravel and sand, which were moved and deposited elsewhere as a result of flooding. Above all, I think that we should look for systemic construction solutions, create more green areas in cities (which also reduces urban heat islands) and aim for urban areas that quickly drain water in the case of flooding (also with permeable materials) -managed not only by the material, but by a complete drainage system able to prevent municipal water from mixing with potable water. In this area, we want to make the general public aware of the potential dangers of the built environment in the event of or after catastrophic natural events, e.g. the handling of asbestos roof tiles and other hazardous construction materials in the event of hail. As far as climate impacts are concerned, we also work in the field of wastewater treatment, ensuring that the water, as well as the waste generated in the process, are both reused.

Is the comfort of living in our dwellings better due to the improved properties of materials?

One of the trending actual topics for building materials is the use of natural and traditional materials, such as straw, hemp, and clay, in a more modern way e.g. using additive manufacturing or 3D printing technologies. An important shift in the use of natural materials in society is the use of not only wood, but also natural fibers and biobinders in the construction industry, replacing conventional polymer binders in composites, also for structural purposes. I think that in the so-called circular bioeconomy this will be given even more emphasis in the coming years.

What investigations will the recently purchased microtomograph allow you to perform?

It will allow us to see better (i.e. at a higher resolution), faster (i.e. a faster scanning time and resolution) and wider (i.e. a more diverse range of materials). Compared to the device we have been using for the last 10 years, we can now analyze larger pieces of material, view objects at a higher resolution, perform faster analyses in different scanning modes, and create better reconstructions from 3D scans (also with AI tools). Above all, our integration internationally is intensifying, both with industry as well as with research and educational institutions around the world. We recently became involved with one research project because of our ability to perform microCT characterization of post-Li batteries, which can have the same or better energy storage capacity as Li batteries but are not explosive. Such storage systems are also less dependent on the critical raw material, lithium, which is only produced in small quantities in Europe and is largely dependent on imports from geopolitically unstable countries.

What are the biggest challenges in your work?

Multitasking and lack of staff. I'm always proud of our researchers and what they can do, but I know that it's hard to be a scientist trying to be scientifically excellent, while at the same time getting funding and being an expert in the market. This means a very interesting way of working, as we adhere to the ZAG tradition that our scientists are anchored in real problems, that we know the field perfectly and are not somewhere high in the scientific spheres, but it can also be very stressful and tiring, with a great responsibility towards funders (public or private), our customers and the general public. At the same time, of course, we all take care of our private lives and families, which can sometimes be a challenge, despite all the favourable conditions offered by ZAG (e.g. work from home option, a flexible work schedule, excellent infrastructure etc). I think that we are at a turning point as an institution, whereby we have a lot of potential both in marketing and research work, but this means new management challenges. There is a Japanese saying that stagnant water starts to stink. Progress is a natural process - how we do it to make growth as sustainable as possible is probably up to all of us. I definitely see opportunities for us in near-to-market research and transition of our solutions to market, as well as development and innovation between excellent science and expertise, which we have already partially tackled, by being a protagonist of development in industry and not just providing industry with our services. This is, of course, a challenge in itself, as it is a difficult path. It's no coincidence that the area between technological readiness levels 5 and 8 is called the "valley of death", since many innovations peter out here and do not penetrate into the marketplace. For us, the challenge is slightly different – namely, through testing in real environments, including the development of pilot technologies, we can obtain funds and develop knowledge, products and technologies, but it is more difficult for us to market these products or even go on an independent entrepreneurial path.

How do you see your department in 10 years?

There are many variables that will affect this. When I assumed my position I said that our goal was for one or more of our researchers to receive funding from the European Research Council (ERC) in the next 5 years. In the future, I see professionals who can successfully solve even the most difficult challenges. I see satisfied employees who enjoy their work and their successes and know how to take care of themselves and their colleagues. I'm happy to be part of this exciting voyage.

Balancing People's Needs with the State of the Environment

doc. dr. Katja Malovrh Rebec
Head of the Department for Building Physics

What are the main activities your department is currently involved in?

The Department of Building Physics is currently focusing on a wide range of activities, including international and national research projects in teams of renowned scientists as well as professional work, standards-compliant testing in the laboratory and field work. We measure and calculate the thermal characteristics of materials and building elements. We also test windows and shading systems for the purpose of reporting their water tightness and wind resistance. In the acoustics laboratory, we measure the acoustic characteristics of building elements. We study, measure and calculate how building materials affect acoustic comfort, and we also evaluate spatial acoustics and field measure the properties of surfaces to reduce noise. For more complex buildings, we prepare detailed building physics calculations. Recently, we have started to work intensively on measuring the response of people to different indoor conditions, using advanced data capture and analysis combined with machine learning. We have set up a new laboratory and added the evaluation of lighting conditions and direct human responses to our measurements. We are actively shaping the domestic and international market for Environmental Product Declarations (EPDs). These certificates provide transparency and environmental information to the public. Our team members are involved in national and international associations. Two current team members are continuing their education at PhD level, with a third to be joining us shortly, and we are particularly proud of them. The head of the unit teaches the compulsory course, 'Energy Efficient Buildings Design' at Master's level.

Which parameters of building physics have improved the most in the last 100 years?

In particular, the related understanding of the interplay of what we understand as building physics has improved: heating/ cooling, air quality, acoustic and lighting conditions, energy use and related financial and environmental aspects, and the overall comfort and well-being of people in buildings. We are now able to predict with much greater confidence how buildings will behave once they are built. There is no doubt that over the last 100 years there has been an unprecedented improvement in the way we approach how to insulate buildings, which has led to more energy efficient buildings, a smaller environmental footprint, and also increased the comfort for people inside the buildings. Advanced materials and elements that effectively improve thermal, lighting and acoustic conditions have been developed, thus increasing the comfort of people indoors. We are integrating systems to make buildings increasingly autonomous. We know more about the durability and sustainability of materials, which have an impact on the lifetime of buildings and can reduce the need for renovation and lower our environmental footprint. There has also been a significant change in terms of the use of standards and regulations over the last 100 years. We have introduced systematic testing of building elements and materials, allowing the assessment and comparison of their performance to be better and fairer. 100 years ago, building design was very different from today, and we have learned to connect and communicate with each other much better. We use approaches such as Building Information Modelling (BIM), a process underpinned by a range of tools, technologies and contracts that involve the creation and management of digital models to describe the physical and functional characteristics of the built environment. Data is captured by sensors and managed by digital twins, with decisions informed by feedback loops.

What improvements do you think would make buildings more resilient?

Improving the resilience of buildings to climate change, in particular to increases in the average temperature, is becoming a focus of our research. Specifically, we are considering adjustments to the design and materials used in a building, for example for insulation and shading, which have a significant impact on reducing the demand for cooling. Cooling and air quality are becoming more of a concern than heating. We are also considering future building designs that could make much better use of natural shading, passive cooling and ventilation. The installation of green roofs and facades that absorb heat and improve the microclimate is becoming more and more understood. The use of smart technologies to optimise the performance of systems is also important. In view of recent extreme weather events, resilience is also enhanced by improved rainwater drainage systems. Regular inspection and maintenance of facilities to detect and repair damage is likely to become more important. Again, here, I cannot overlook the crucial aspect of cooperation between different disciplines and the building of trust. In order to address the complex challenges related to the future of resilience, it will be necessary to involve experts from different disciplines.

Are you currently involved in any interesting projects?

We are currently involved in several research projects, both Slovenian and international. One project, for example, focuses on improving circular building practices, with the aim of reducing the consumption

of natural resources and reducing emissions. We have also developed a guideline that is particularly useful for public procurers. In another international project, we are creating a digital building logbook based on a decentralised knowledge graph. It is designed to improve construction quality, increase efficiency and reduce environmental impacts and footprints. Another international project focuses on the development and implementation of innovative solutions for healthy and environmentally-sound buildings, particularly in terms of the development of building technologies and the testing and standardisation of these technologies. We are also working with local scientists to develop technical guidelines for four-pane glazing. Furthermore, we are involved in a study on the thermal performance and environmental impact reduction throughout the lifetime of alternative building elements. These are just a few of the projects our group is currently working on.

How do we focus on measuring people's response to indoor building physics parameters in breakthrough research?

As people spend most of their time inside buildings, it is important to provide conditions that are comfortable and resource-efficient, and bear the health and general well-being of the occupants in mind. Lighting, for example, provides both visual comfort and other benefits to the occupants of a space. Lighting directly affects the secretion of hormones that help us maintain our circadian rhythms, but, in the long term, an imbalance can cause depression and an increased incidence of certain cancers. Human beings' perceptions of thermal, acoustic, light and other indoor conditions are connected. The needs of individuals can vary considerably depending on their age, background, type of work and so on. It is therefore important to learn how to measure direct responses and to extract people's responses through advanced analyses, then to adapt buildings accordingly, so that buildings of the future can meet the needs of users with the optimal use of resources.

What are the biggest challenges in your work?

The challenge for our team members is to effectively balance management, research, teaching and family commitments. We therefore focus a lot on effective organisation and developing the ability to prioritise. Our team motto is to listen to each other, respect each other and put a lot of emphasis on relationships. Building physics is a rapidly evolving field, so it is necessary to constantly keep up with new developments and learn and adapt our approaches. We also focus a lot on skill building, which enables us to obtain funding for research projects. All team members are encouraged to build on their leadership and communication skills. Some of us are also involved in teaching work at partner institutions. This means further aligning the interests of students, faculty and industry to ensure a relevant and quality education. In my opinion, the biggest challenge of our time is to find a balance between the different demands. To me, building physics seems to be a meeting point, where we see societal changes such as climate change and sustainable development, and we have a responsibility to help with the solutions we urgently need for the future. This requires flexibility and innovation. It also requires trust in ourselves and in our fellow human beings.

What would be your ideal house?

My ideal house adapts to the different needs we all experience as we move through life. It grows bigger and smaller as needed, and materials and elements are reused and adapted to be reused even when they are no longer built into this house. It allows

me to work, explore, think, rest and play. It means a lot to me that it is in harmony with the environment and that it has minimal impact on the environment. My ideal house is also a testing ground for advanced and less standard solutions, such as passive approaches to heating, cooling and ventilation, and has a well-thought-out design for the translucent parts of the façade, including location-specific shading systems, and the use of a solar chimney.

How do you see your department in 10 years?

In 10 years' time, the Department of Building Physics will have a world-class team of experts and a new building where our laboratories are combined with state-of-the-art equipment. The team members of the Department of Building Physics will be top scientists and experts in their field who regularly receive the most prestigious awards for their work, both at home and abroad. We will regularly publish cutting-edge scientific papers and write books, which we will be proud to promote at various events and conferences. We will actively participate in projects focusing on sustainability and environmental aspects of the built environment, and help to ensure that occupants of buildings experience superior conditions in terms of the building physics (heat, light, acoustics). We will work with a wide range of national and international institutions and companies. We will be known as a first-class, impartial and reliable partner. Business leaders and public institutions will rely on our results and look to us for expert opinions. In addition to sustainable solutions that enable quality living on Earth, we will be key members of the teams that will create the first Lunar Village and facilities for extended travel and stays in space. We will be able to demonstrate our wealth of knowledge in the field of human responses to different parameters of the built environment. In this way, we will contribute to scientific development, in addition to improving the living environment for all.

Fire Safety in a Sustainable Built Environment

prof. Grunde Jomaas
Head of the Department for Fire-safe Sustainable Built Environment

Can you give a brief description of the department?

The main location of the Department for Fire-safe Sustainable Built Environment is ZAG's Fire Laboratory in Logatec. In total, the department has 25 employees, split across two sections. The Fire Laboratory and Fire Engineering Section, led by Friderik Knez, has 15 employees, while the Fire Research and Innovation section, led by Aleš Jug, has 10 employees. We have collaborators and clients from all of Europe, and even some from other continents. It is therefore an asset that the personnel in the department speaks more than 10 languages.

What are currently the main activities in the department?

We carry out two main activities in the department - namely research and accredited fire testing (reaction to fire and fire resistance). As the name of the department implies, we focus on research for a fire-safe sustainable built environment. The main experimental research topics are related to photovoltaics, batteries, biobased materials and mass timber. We are also involved in desktop research related to fire safety and sustainability. As such, our work is well-aligned with the current priorities on a European level, such as Green Deal, RePowerEU, New European Bauhaus and the Energy Performance of Buildings Directive.

What are the biggest challenges in your work?

Currently, there is considerable pressure for the fast implementation of new construction solutions. As a result of the fast development, many suggested solutions cannot be tested or assessed according to the existing methods. Every test therefore requires more planning and discussion, as without standards to follow, we end up giving recommendations in our reports, rather than classifications. Thus we must be even more careful in our work, as we must be sure that our recommendations are applicable generally.

What are the strengths of the department?

We have state-of-the-art facilities and outstanding personnel to carry out the projects and testing. The

ZAG fire laboratory, which opened in 2022, was designed with knowledge based on ZAG's 50 years of experience in fire testing and research. Our staff includes a mix of very competent technicians and engineers with significant experience and researchers with PhDs in many different fields. This combination allows us to take on challenging and highly-complex R&D projects.

How do you share the knowledge that you generate in the department?

We share the findings from our work through popular and scientific articles, in seminars and workshops, in newspaper and television interviews, at conferences and in webinars, as well as through guidelines. The seminars and workshops are often co-arranged with SZPV (the Slovenian Fire Protection Association) and many times also with the Protection and Rescue Training Center in Ig near Ljubljana. It is very important for us to work with other Slovenian stakeholders so that we ensure our knowledge can make a difference here in Slovenia. Dissemination of information on a national level is also done through Požar, the main publication related to fire safety in Slovenia, which is published by SZPV four times per year. Finally, we also contribute at many conferences around the world.

How do you market a fire laboratory in a small town like Logatec for international clients?

Actually, it is easier than you would think. Some of it comes very naturally, through ZAG's long and solid history with respect to fire testing, which is further supported by its membership of EGOLF (European of Organisations for Fire Testing, Inspection and Certification). An important aspect of EGOLF is close collaboration with respect to sharing knowledge and skills, as well as a continuous effort towards excellence, which is achieved through numerous round-robin studies to make sure that test results from laboratories across Europe are aligned. Furthermore, our researchers in the department are involved in many European projects and this creates good visibility, both directly through experimental work and indirectly through dissemination activities (e.g. conferences and webinars) and word-of-mouth. Finally, we see that our webpages, which are continuously updated, along with our active use of LinkedIn, create very good visibility, and have resulted in us getting work with international clients, even beyond Europe.

Would you like to mention an interesting event that has shaped your career?

I think that, more so than specific events, my career has been shaped by my mobility, and my willingness to move to explore new challenges and opportunities. After studying in two different educational programs and cities in Norway, I moved to the US, where I again studied in two different programs and cities. After the completion of my PhD, I have worked in France, Denmark, Australia and Slovenia, and it is the sum of all these experiences and the people that I have met and worked with along the way that shape me as a researcher and a leader.

How do you see your department in 10 years?

In 10 years, I hope that, based on the timeliness and quality of our work, we are recognized as a leading lab for fire research and testing, as well as for the expertise that our staff offers. As a result of this, we will have steady operations with a balance of national and international research projects, R&D partners and clients for accredited testing. We will also have expanded our range of operations to offer a larger range of services, so that we can serve and advise companies and governments even better than we do today.

Safe and Durable Structures

dr. Iztok Klemenc
Head of the Department of Structures

What are the main activities of your department at the moment?

About half of our resources are directed into various research and development projects in the broader field of civil engineering. Traditionally, we continue our multi-year research to reduce the seismic risk of masonry and concrete buildings. Research into multi-storey timber buildings is currently underway, as is research into the use of timber in composites and the potential of alternative adhesives. In the infrastructure segment, we are researching the safety and durability assessments of existing bridges and, following the trend towards a circular economy, developing the reuse of old bridge elements. In the professional field, we prepare condition assessments of buildings as the basis for rehabilitation or seismic strengthening, whilst in the construction and maintenance of national transport infrastructure, we carry out both extraordinary and regular inspections for DARS and provide condition assessments on bridge structures. Through technical approvals and certification procedures we are involved in placing construction products on the Slovenian and European markets.

Which projects do you find particularly interesting that you would like to highlight?

In terms of providing support for decision-makers, we would like to highlight the CRP ARIS research project, "Strategic basis for reducing the seismic risk of judicial buildings in Slovenia", co-funded by the Ministry of Justice, in which 49 selected courts are being categorized according to their seismic risk. As part of this project we carry out in-situ investiga-

tions and non-linear static analyses of the existing state as well as of the strengthened state according to different design options. Within the project, we will also evaluate the financial aspect of the various options for building reinforcement. The professional project, "Quality Assurance in Sustainable Timber Construction", is important for enhancing the technical culture in the field of quality timber construction. Another interesting research project is CIRCUIT, in which we are developing an integrated approach to promote the circular economy of transport infrastructure. Together with our partners we will build a new bridge in Črna na Koroškem, using beams from an existing bridge set for demolition.

How do you perceive the impact of climate change and recent storms on structural damage?

Weather patterns have changed in recent years, as reflected in the volume and intensity of rainfall, with more frequent hailstorms and high wind speeds. Storms reveal the vulnerability of older buildings in particular. A few years ago we carried out a project on this topic, "Roofing Damage in Summer Storms", in which we realised that the state of the building before the storm occurred should also be considered when assessing the damage. Damage to buildings in storms cannot be avoided completely, but it can be mitigated with minor measures, such as the installation of additional anchoring for the roof structure. That said, the resilience of buildings to storms depends not only on their structural design but also on their siting, with landslide and flood-prone areas being particularly problematic. Prolonged heavy rainfall and torrential downpours cause sharp rises in the levels of watercourses; last year's storms showed that a combination of ill-considered designs and the intensification of erosion by debris are key factors in the development of severe damage, with some bridges collapsing during floods. Quite coincidentally, at that time we happened to be studying these issues in the European projects oVERFLOW and CROSScade, which developed methods for assessing the flood vulnerability of bridges.

In your opinion, is the issue of seismic safety in the built environment still relevant today?

Of course, stronger earthquakes are expected in Slovenia, but they are often forgotten due to their infrequent occurrence. Stronger earthquakes will affect bridges. Although we do not expect large-scale bridge collapses in Slovenia, some damage will certainly occur, which can have a serious impact on the fluidity of transport infrastructure, so proper assessment and decision-making are essential for the safe use of infrastructure. At ZAG, we started to assess the seismic risk of building stock decades ago, when seismic loads were still very much underestimated. Over time, regulations concerning the need for an earthquake-resistant design have advanced significantly, and as a result, the strengthening of many older buildings is necessary! Over 10 years ago, alongside our partners, we developed and then repeatedly upgraded the POTROG model to assess the seismic risk of buildings for earthquake protection and rescue planning. As part of this project, the "Assess Your Building" app was also developed, which allows owners to get an indicative assessment of the damage that would occur to their building during a design earthquake.

The use of timber as a building material is experiencing a renaissance, but the origins of timber construction at ZAG are said to go back much further?

The field of timber structures was recognized as important four decades ago, when the Section for Tim-

ber Structures was created. At that time, timber was the primary load-bearing material for roof structures and temporary buildings. Our building inspection activities have evolved into industry liaison, in the form of a wide range of mechanical laboratory tests, while today we also play an important role in the areas of technical approvals and certification. We have always been in contact with educational institutions, we are strengthening our cooperation with domestic and foreign research institutions through projects, and our competencies are also recognized by ministries, who have entrusted us with implementation of the projects "Storm Damage" and "Quality Assurance in Timber Construction". We continue to support the popularization of timber construction, but on the other hand we are also aware of the specificity of timber as a material and the complexity of timber construction, which is often not given enough attention in practice.

What will be the impact of digitization and artificial intelligence in the field of load-bearing structures?

When analyzing buildings, digitized documentation can save us a lot of time in identifying the design and modifications to the structure. We expect major advances in the tools and systems used for inspecting and monitoring facilities, especially for those with higher risks or negative consequences in the event of their failure. Digitalization and artificial intelligence are noticeable in the development of measuring and testing equipment for the execution and processing of measurements, the deployment of smart sensors and advanced measurement technologies, as well as in the processing and use of spatial data. Artificial intelligence is enabling greater capabilities in research tools, while the impact of digitization is reflected in the increased availability of a variety of measurement data, enabling more advanced research and increasing the efficiency of systems maintenance and asset management. In the future, the design, condition assessment and maintenance of load-bearing structures will be strongly linked to digitalization and artificial intelligence, thus improving efficiency and safety, enabling innovation, and leading to the development of more sustainable building solutions. In addition to these advantages, we also need to be aware of the limitations, in that irresponsible use can lead to incorrect results for future decision-making.

In your opinion, is the topic of load-bearing structures overshadowed by the energy renovation of buildings and the green transition?

The focus of European building renovation policy over the last 15 years has been on energy renovation. Given the increased seismic risk in Slovenia, this type of renovation on existing buildings usually first requires further, more comprehensive construction work, including structural strengthening. Not without good reason, mechanical resistance and stability are the first essential requirements to be met by each structural element, as well as by the structure as a whole. In this context, we also identify the provisions of the Building Act to be problematic, as they allow for buildings of longer standing to be legalized merely on the basis of their age, without verifying their mechanical resistance and stability or their potential threat to neighboring buildings and the surrounding area, especially in dense built-up areas.

Which structures have improved the most over the last 100 years?

Over the last 100 years, there have been huge advances in our understanding of the behaviour of structures under different loads. Standardized guidelines have been introduced for the design and

construction of structures, and developments and advances have been made in terms of building systems with different materials and technologies. Here we are referring to the appearance of reinforced concrete and prestressing technology, which have made the shapes and dimensions of today's modern bridges possible, whilst there have also been huge advances in masonry construction. Finally, it is worth mentioning the leap forward in timber construction, with the rapid development of cross-laminated CLT panels, which, either alone or in combination with steel and reinforced concrete, make it possible to construct buildings of dimensions that were previously unimaginable.

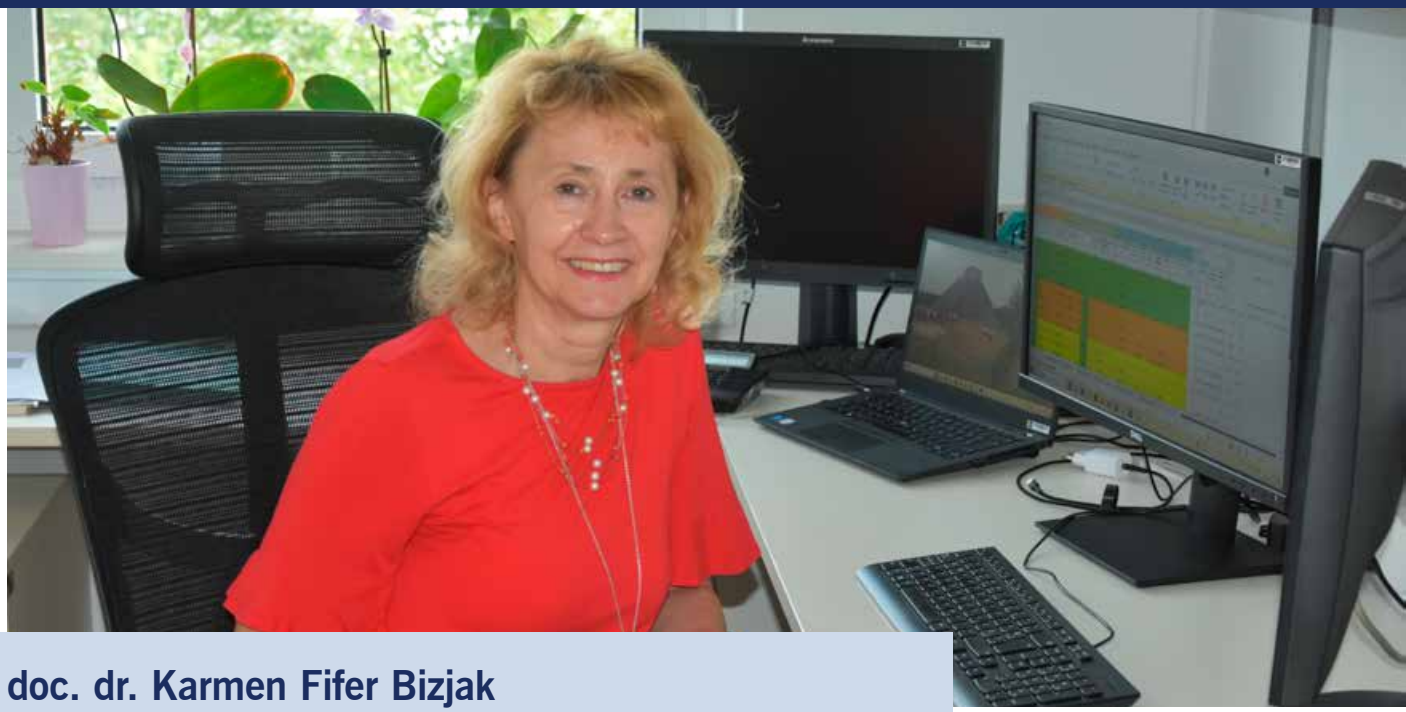
Do you consider that the level of supervision in the construction of facilities is sufficient?

Due to developments in materials, and the complexity of modern construction, designers, contractors and supervisors require a good knowledge of all areas, and are often faced with specific tasks for which they do not necessarily have sufficient knowledge or experience. In these cases, it is particularly dangerous to reduce the scope of supervision, as this can have a negative impact on the quality of construction - we therefore advocate the establishment and maintenance of strict standards and the consistent application of supervision, including external quality control and revision of project documentation. This was the approach adopted by DARS when construction of the motorway network began almost three decades ago, with external quality control conducted by experts from ZAG, whose knowledge and experience helped the supervisors, the investor and, to a certain extent, the designers.

What are the most challenging aspects of your work?

All sections of the department carry out their testing in the Laboratory for Structures, which places considerable pressure on the allocation of laboratory resources, making it a constant challenge to fulfil all priorities. We are faced with constraints in the labor market in terms of staff availability, which will pose a barrier to the transfer of knowledge and experience when our long-standing colleagues retire and subsequently make it difficult to maintain high quality standards. A significant challenge is how to integrate the different issues of load-bearing structures into current calls for the Green Transition and a Circular Economy. It should be noted that the experimental testing of structural elements and systems is very costly and time-consuming, requiring large, realistic samples, and a modern testing infrastructure with experienced experts to carry out the tests and interpret the results. In general, legislation associated with a public procurement system remains a daily challenge, with low prices still prevailing over professionalism – even though the lowest price typically negates the extent and quality of the service, which generally require more time and better materials.

Challenges in Geotechnics and Transport Infrastructure



doc. dr. Karmen Fifer Bizjak
Head of the Department of Geotechnics and Traffic Infrastructure

What are the common challenges in geotechnics and transport infrastructure in the future?

The fields of geotechnics and transportation infrastructure face several common challenges that need to be addressed to ensure the safety, sustainability, and efficiency of infrastructure projects. With the increasing impact of climate change, in addition to ensuring soil stability and load-bearing capacity, it is also necessary to consider the effects of extreme weather events. The increased frequency of climatic events such as intense rainfall, floods, droughts, and high temperatures affects the stability of soil and the durability of infrastructure. The limited space for new transportation infrastructure in urban areas means innovative solutions and technologies are required that minimize disruptions to both residents and existing structures. Sustainable construction relies on the use of advanced technologies and recycled materials.

How do you integrate the principles of sustainable construction into your research?

Extensive research is being conducted on new bridge constructions with supports that ensure the stability of the bridge even during periods of extreme river flow, as experienced during the floods last year. The technology to construct bridge supports from

reinforced soil has been successfully transferred from laboratory investigations to a real-world environment with the bridge over Pavlovski potok in the municipality of Ormož. This technology is now being enhanced with the use of recycled materials to incorporate the construction sector into the circular economy. This new concept for bridge construction has gained international recognition through publications in prestigious scientific journals. Within the EU project Circuit, a reinforced soil bridge support will also be constructed in the municipality of Črna na Koroškem, using only recycled materials.

Do you face any regulatory constraints in this regard?

Environmental directives regarding the use of recycled materials in construction are very strict, necessitating extensive research at both the macro and microscopic levels to prove the environmental acceptability of such materials, which are mainly used for backfills and embankments. Adding alkaline activators and other recycled products significantly increases the strength characteristics, so future development will focus on stabilizing weak load-bearing materials with additives developed by recycling waste from the construction industry. Preserving natural resources is essential for future generations, as is the reuse of waste that would otherwise end up in landfills, which are already overcapacity. These materials have been developed and successfully used in the construction of demonstration projects in the EU projects Paperchain and Cinderela, while current research is focused on developing materials for flood protection embankments as part of the LIFE IP Restart project.

What is the state of the rail infrastructure?

The construction and modernization of the railway infrastructure in Slovenia has been in full swing in recent years. The development and application of new materials is particularly challenging in terms of the dynamic loads involved and the long-term reliability and stability of the railway track. There is also a desire to ensure all the materials are reused. Within the LIAISON project, we are developing a track bed using recycled stone aggregate mixed with aggregate from recycled waste car tires. A track bed modified in such a way can still provide sufficient load-bearing capacity and stiffness, while also reducing the noise and vibration emissions in the environment. Reducing the noise around transportation infrastructure significantly enhances the quality of life for residents living nearby. These new materials, and the improved track bed, will be used in a demonstration project within the LIAISON project.

Does the old and burdened transportation infrastructure for our roads and railways require thorough renovation or even replacement?

Reliable data on the condition of transportation infrastructure is crucial for making informed decisions. Significant progress has been made in recent years in developing technologies for collecting various infrastructure data as well as advanced methods for processing this data. Technologies such as remote sensing, satellite monitoring, mass data collection, vehicle-to-infrastructure communications, advanced data processing, and internet support significantly assist the detection of critical infrastructure locations and appropriate actions. By utilizing new methods and technologies, the road and railway administrations can better manage the transportation infrastructure.

Are you introducing new methods?

Yes, we have tested new methods in the INFRACOMS project (Innovative & Future-proof Road Asset Condi-

tion Monitoring Systems). These methods, however, need to be carefully adapted to specific environments, such as tunnels, high bridges, dams, large-span viaducts and steep, inaccessible slopes in the vicinity. Developing tools to detect structural damage remains a challenge, but we are addressing this by developing machine learning algorithms for detecting damage in structures of particular importance. Our goal is to develop our own tools for fully automating the detection of damage in hard-to-reach structures, which are challenging from the perspective of worker safety during inspections and traffic disruption or diversions. Incorporating modern remote sensing as a method for assessing the safety and functionality of critical structures will help alleviate traffic jams and reduce driver frustration due to road closures.

What adjustments will be needed with the introduction of autonomous vehicles?

Regardless of the level of autonomy, autonomous vehicles require the establishment and implementation of new concepts and support solutions in the areas of physical (transport), digital, and communication infrastructure. It is necessary to test in closed areas, in traffic, and through traffic simulations to verify the effectiveness of solutions with respect to the functional safety of transportation infrastructure, traffic safety and efficiency, driver behaviour, the environmental footprint, and the reliability of services in traffic. This is addressed in the international research project, Augmented CCAM (Augmenting and Evaluating the Physical and Digital Infrastructure for CCAM deployment).

How can the quality of asphalt, which significantly affects driving comfort, be improved?

Asphalt used in road transportation infrastructure is heavily exposed to climatic conditions. Increasingly, it also incorporates recycled materials, due to numerous environmental and economic advantages. Such additives are not always suitable for practical use, so our research focuses on finding the optimal composition of natural and recycled substances in asphalt mixtures. This can provide environmental benefits and cost savings for contractors and road network operators. The fact that we are addressing these challenges, alongside the results from our research, place our laboratory amongst those most recognized in Europe.

Finally, could you outline the work of your department and your aspirations for the future?

Our work requires a comprehensive and interdisciplinary approach, involving collaboration between geotechnical engineers, civil engineers, chemists, physicists and environmental experts. With numerous European projects underway, we are already firmly embedded in the domain of European research, and we aim to strengthen this activity even further. Close ties with the industry enable us to quickly transfer new technologies and knowledge into practice. Our researchers achieve outstanding success: this year, the Head of the Asphalt and Bituminous Products Laboratory has been invited to the Science and Technology in Society (STS) Forum, where 130 young leaders from research departments and laboratories around the world have been selected for a special meeting with Nobel laureates. The diverse composition of staff at ZAG allows us to push the boundaries of development in the field of construction. We aim to introduce more new, advanced research, and collaborate in the development of technologies that are crucial for addressing these challenges and ensuring a safe, sustainable, and accessible transportation infrastructure.

Calibration of Measures to Ensure their Comparability

dr. Miha Hiti
Head of the Laboratory for Metrology

Why is metrology important?

Metrology is constantly present in all areas of our lives, both private and business. If we want to evaluate something, compare it, or establish consistency, we must first measure it. And as soon as we talk about measurement, we enter the field of metrology. Every measuring device used for measurement must show correct values, which is ensured by calibrating it, that is, comparing it with a reference measure - the standard. Without calibration, the measuring devices would be incomparable to one another. The mission of the Metrology Laboratory is to carry out the calibration of measuring devices, thus ensuring their comparability, be it between users in Slovenia or those around the world.

How do artificial intelligence and digitalization affect metrology?

Performing a calibration is basically a relatively simple process - the indication of an unknown instrument is compared with a reference instrument - but in many areas, the automation of this process is difficult to implement. The presence of a person, who transports the measuring equipment, connects

it, and also manually controls the measuring devices, is generally still required. Some of the test machines we calibrate are older than 75 years, and in such cases it is difficult to talk about the use of digitization and artificial intelligence. In recent years, however, digitization has gone mainly in the direction of digital calibration certificates, which will be exchangeable, readable and comprehensible by machines. With this system, the user of a piece of measuring equipment will be excluded from the process, with our computer able to directly upload the calibration results into the measuring equipment and thus ensure the correct indication. Machine learning algorithms are interesting for more demanding calibrations, where we would like to model the reference measuring equipment, such that the model can be used to correct the values measured according to any unwanted influences during the calibration itself, thereby reducing measurement uncertainties.

Are you currently involved in any interesting projects?

Last year, we completed a four-year international research project related to force measurement under dynamic conditions i.e. those that mostly occur in practice. The goal of the project was to provide adequate metrological traceability and appropriate procedures for dynamic force calibration. Despite the development of new methodologies and proposals for standardized procedures, many open questions still remain.

In which area does metrology have the greatest impact on safety?

Between 2004 and 2009, the laboratory was recognized as the holder of the reference standard for force, hardness and torque, together with the reference standard for the amount of substance. Unfortunately, we lost our official status in 2009, but we still maintain reference standards for force in the laboratory, which are of the highest level in Slovenia. During all this time, we have regularly upgraded and expanded the scope of reference standards, thus ensuring comparability with foreign calibration laboratories and national institutes of metrology. We can say that we carry out activities as if we were officially designated as a national standard in the field of force: we provide the best calibration and measurement capabilities, organize interlaboratory comparisons, conduct training, perform research and publish scientific papers, participate in international research projects and more.

What are the biggest challenges in your work?

The biggest challenge in our work is the constant checking and control of the integrity of our measurements or our work. Each of our results and calibration certificates guarantees metrological traceability to a large number of measurements, meaning one wrong result from us can cause a domino effect - all further results will be wrong. Sometimes we feel like we spend more time and energy checking our work than actually performing the calibrations. Each of our calibrations must be correct and reliable, i.e. one that we trust. Another big challenge is to demonstrate the importance of calibration results to the users, so that they know how to use them correctly and take advantage of the potential they offer. It is important that they are seen as a validation of the process or an opportunity for improvement, rather than just an unnecessary expense.

What do you think your lab will look like in 10 years?

I don't think the laboratory will change significantly in 10 years. Apart from the digitization of the calibration certificates, which I mentioned already, most of the reference equipment will remain the same, and we will still need personnel to perform calibrations and working space for the reference equipment. 10 years is a rather short time in our field - to justify low measurement uncertainties, our reference equipment only proves its stability over time. Based on the experience of recent years, however, we will expand the calibration procedures to dynamic forces and the field of torque calibration, which goes hand in hand with the field of force, as well as the field of hardness. Otherwise, we would be happy if the Metrology Institute of the Republic of Slovenia would finally recognize our reference machines as national standards, and we would appreciate as much international cooperation and as many interesting research and development projects as possible.

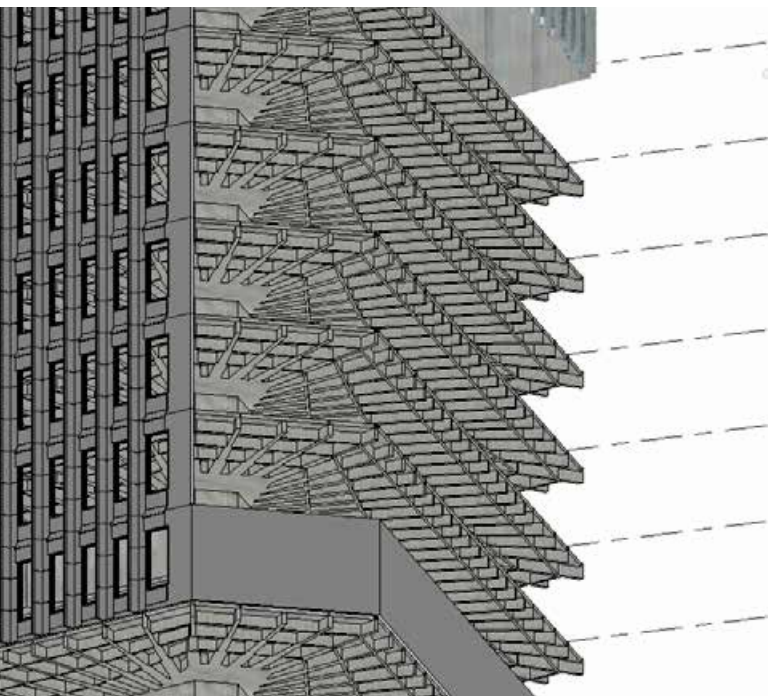
ZAG's Contribution to Solving Social Challenges

Heritage Science

doc. dr. Sabina Dolenec
dr. Mateja Golež
Ana Brunčič

The treatment of heritage is one of the permanent activities at ZAG, and this is currently dealt with as part of the internal, transdisciplinary group of researchers, sHERezad: Sustainable Built Heritage. Diversity and width, extensive experience, international connections and a wide range of skills and equipment ensure the competence and credibility of the group.

Cultural heritage reflects the identity of diverse cultural environments, meaning it should be preserved holistically and managed as a source of sustainable development. The field of heritage science is rapidly developing into an independent science that requires a distinctly interdisciplinary approach. The foundations of its development originate from the natural sciences, in close connection with the humanities, both of which are today connected with modern digital technologies. Slovenia has a rich and diverse heritage, which is closely related to the built environment of villages, squares and cities, and, within these, to individual buildings currently in existence - the values of these must necessarily, therefore, influence the construction of new buildings. When it comes to understanding and preserving heritage and its sustainable use, its documentation, study, integration into modern life, and safe use are of key importance, as are enabling access, education, popularization and integration into interdisciplinary development projects.



ZAG is a distinctly interdisciplinary research institution, and through the 75-year history of its operation it has acquired rich national and international experience in the field of cultural heritage research and heritage science. Modern trends in society are oriented significantly more towards the renovation of building heritage than in the past, as seen by the New European Bauhaus, the Green Deal and other programs in the field of cultural heritage, and in light of this we strive to transfer the results of our research work into everyday practice. At the same time, we strive to connect science, art and the economy even more strongly, in a way that will be reflected in space by renovating and thus preserving more cultural heritage buildings which is key to preserving our historical space and identities in the future.

The heritage science at ZAG covers the characterization, synthesis and analysis of materials and systems for strengthening, structural systems and their load-bearing capacity and resistance, load-bearing analysis, implementation technology, geomechanics, environmental impact analysis, digitization, and

earthquake and fire resistance. Recently, we have been more and more involved in analysing the impact of climate change on the condition of heritage objects, and have introduced non-invasive and non-destructive techniques to characterize or monitor their condition. By combining a wide range of approaches, we ensure that heritage is treated in a holistic way: i.e. the development of techniques, methods and ways of characterizing and monitoring processes that affect the preservation of heritage. In addition to a wide range of activities in the field of cultural heritage research, we also place a strong emphasis on education. As such, at the beginning of July this year we organized our 1st International Summer School (2024), entitled "In situ techniques in the preservation of architectural heritage".

The group is an active co-creator of heritage science, through publications as well as through our membership with several organizations, including the European Research Infrastructure of Heritage Science (E-RIHS), the International Council for Monuments and Monumental Areas (ICOMOS), the Association of Conservators of Cultural Heritage of Slovenia (SKD), the Slovenian Society for Conservation-Restoration (DRS), the Slovene Association of Historic Towns, Global Heritage Stone, the Scientific Advisory Board for X-ray MicroCT Activity at the VisionLab and the European Construction Technology Platform/ Cultural Heritage Area (ECTP C). We are also regularly involved in solving professional heritage problems, and participate in national exhibitions and research projects, both at home and abroad.

The group aims to deliver sustainable solutions to real-world cultural heritage problems through cross-disciplinary research and innovative knowledge transfer. With access to modern and cutting-edge scientific facilities, the project provides a full range of analytical techniques and scientific methods and enables their application to real-world heritage challenges. The inclusion of a wide team ensures that expertise is drawn across many disciplines - not only from within the Institute, but also from within the distributed research infrastructure network E-RIHS, a community of experts with an interest in cultural heritage work. The group addresses one thousand and one stories captured across 4 crucial research themes: 1) heritage science, 2) heritage risk and resilience, 3) modern and contemporary heritage, and 4) future heritage.

Heritage science is a rising cross-disciplinary research area that combines understanding of the past with the management of heritage. It is enabled by state-of-the art infrastructure, equipped with material science instrumentation, some of which – such as non-destructive techniques – are portable, so can be employed in situ with heritage stakeholders. The inclusion of imaging and analysis techniques enables visualization of an artifact, object or building, detailing their structure and the composition of surfaces. One part of heritage science is citizen heritage science i.e. bringing heritage closer to the public.

Heritage risk assessment and ensuring the resilience of heritage objects to various phenomena, from fire to earthquakes, is necessary for heritage practitioners to manage, interpret, and enhance heritage. It

includes the development of novel and integrative methodological and theoretical frameworks and addresses participatory heritage management, heritage-led sustainable development, energy and heritage, heritage values and heritage in conflict.

Modern and contemporary heritage deals with materials that have made new forms of artistic expression possible and demonstrate key scientific advances of the last 150 years. Focus is placed on identifying materials, understanding degradation processes, developing conservation strategies, and understanding and communicating the significance of these objects.

Future heritage deals with heritage that does not yet exist, and may require new approaches to the way heritage is theorized, curated, and protected. It seeks to explore the ways in which heritage can contribute to society successfully adapting to a warmer, more complex, and more uncertain world.

Digital Fabrication Hub – 3D Printing

dr. Lucija Hanžič

Efforts to digitalize the construction sector began in the 1990s, when the increasing amount of data collected digitally, in addition to the widespread use of software tools, spurred the need for efficient storage and access to generated data. This led to the development of BIM (Building Information Modeling) and digital twins. Global shortages in the labour market, however, alongside the ambition to rationalize the use of material resources, have incited the construction industry to also implement digital tools in fabrication processes. Following recent advancements, the deployment of autonomous robots and human-robot collaboration is becoming feasible even in the dynamic conditions of construction sites, thereby transforming the way we think and how we build urban environments.

ZAG recognized the potential of digital fabrication in construction and responded by forming a 3D printing group in 2018. Due to rapid development and growing interest, the group was transformed into a Digital Fabrication Hub (DFHub) project team in 2023. Our team brings together over 20 ZAG researchers from different areas of expertise to comprehensively address various aspects of digital fabrication - from materials, technological aspects and the mechanical, physical, and fire-related properties of products to the development of new methods for testing and assessing digitally-fabricated elements. The group's current focus is digital additive manufacturing, commonly known as 3D printing, which is the type of digital fabrication with the foremost implementation potential.

The most suitable techniques for 3D printing construction elements are selective binding of granular materials and extrusion. Selective binding utilizes either inert or reactive granular materials spread across the printbed in thin layers. This application of layers is followed by the passing of the printer head, which either selectively applies the binder or activator or, in the case of metal powders, selectively melts the metal powder with, for example, a laser beam. In contrast to selective binding, extrusion printing requires cohesive, plastic materials. These are materials whose internal cohesive forces ensure the unity of the mixture and its suitability for plastic shaping by pressing it through a nozzle. The digitally-controlled device, i.e. the printer, deposits the extruded filaments layer by layer, before the transition from plastic to solid state occurs. Rigidification of the extruded filaments stems from chemical or physical processes, such as the hydration of cement or the drying of clay.

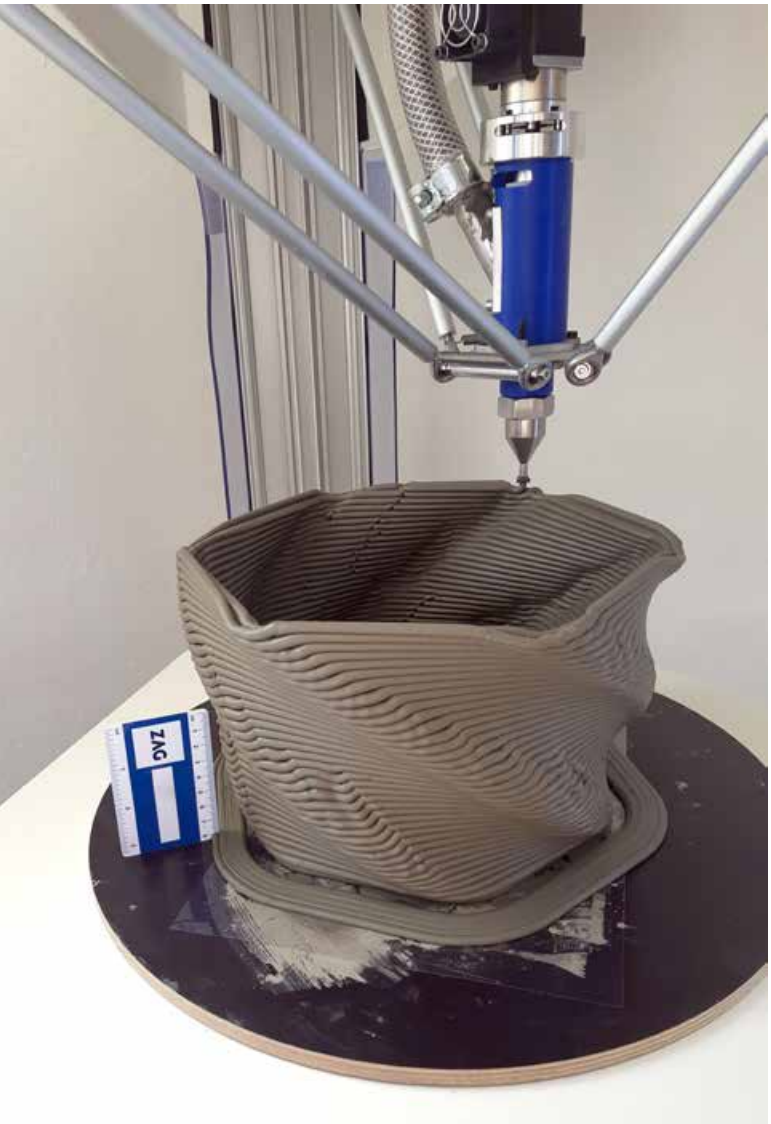
ZAG's team operates three printers for research purposes: one that uses selective binding of granular materials and two extrusion printers. The printer for the selective binding of granular materials, a ZPrinter 310, has a 200 mm × 250 mm printbed with a print height of 200 mm. This printer is suitable for printing with fine-grained reactive powders, onto which the print head drips the activator. The smaller of the two extrusion printers, a Delta WASP 40100, features a 400 mm diameter print surface with a clearance of 1 m. The printer has two interchangeable print heads: a gravity-driven head suitable for cement mixtures and a pressurized head for clay materials. The larger printer is actualized in the Robotic Station for Digital Fabrication, the central part of which is an articulated robotic arm, the KUKA KR240 R2700, with six degrees of freedom, a reach of 2.7 m, and a payload of 240 kg.

A print head for one-component (1K) printing, with a fixed round nozzle, is attached to the robotic arm. The material is fed to the printhead and pressed through the nozzle with a MAI 2PUMP Pictor 3D pump.

Given the large quantities of materials used for the production of buildings and infrastructure objects, it is imperative to source materials available locally. At the same time, the use of such large quantities opens up new avenues to utilise waste from other industries as raw materials. Our team at ZAG has successfully developed a formulation for selective binding from waste gypsum and a formulation for extrusion printing that includes red mud from the production of aluminium and waste dust from stone-cutting operations. The sustainable use of natural resources is also possible by utilizing materials with reversible properties or those from renewable sources. An example of the former is construction with earth, whose use is currently limited

due to the lack of technology. ZAG has demonstrated the feasibility of using loam in 3D printing through the fabrication of a scaled-down model of a pavilion. Our researchers have also studied the use of renewable materials, investigating filaments made from polylactic acid combined with wood filler. The transferability of knowledge to other areas of community activities is most notable in printing with metal materials, where ZAG have participated in the development of alloys for 3D-printed dental implants and inserts.

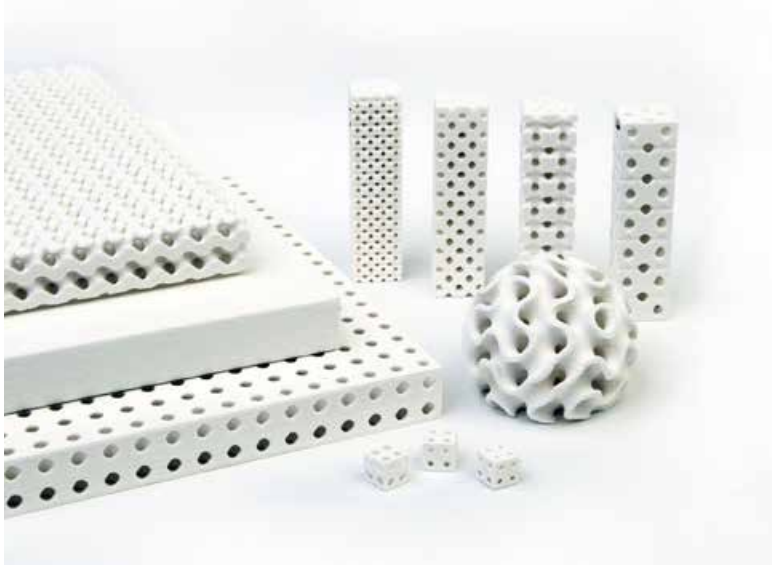
ZAG's expertise and research capabilities, which enable not only the fabrication of printed components but also the characterization of inputs and outputs



on a micro and macro scale, are recognized by both industry and the research community in Slovenia as well as abroad. In 2024, our active projects involving 3D printing are Circuit, Transition, and 2F-3D Print. In the Circuit project, which is funded through Horizon Europe, ZAG have partnered with the Municipality of Črna na Koroškem to construct a pilot bridge over the Meža River. In addition to other innovative solutions, such as geo-reinforced earth abutments and a modular superstructure made from reused beams and prefabricated slabs, the safety railing on the bridge will be made from 3D-printed elements. In the Transition project, funded by M-ERA.NET, ZAG is involved in developing a pre-blended dry mixture containing oil shale ash which is suitable for extrusion 3D printing. 2F-3D Print is a national project in which a new type of extrusion printer will be developed in collaboration with an industry partner and the University of Ljubljana.

ZAG's DFHub researchers are also active members of various international associations. Most notably, our team has participated in inter-laboratory studies as part of two RILEM's technical committees: namely, 303-PFC, "Performance requirements and testing of fresh printable cement-based materials" and 304-ADC, "Assessment of additively manufactured concrete materials and structures." The purpose of both of these studies was to prepare guidelines for testing cement-based materials so as to evaluate their suitability for extrusion printing.

In addition to studying the mechanical characteristics and resistance to environmental degradation, new



methods were also investigated, such as assessing the rheological properties through the size and shape of extruded filaments, and a portable device for measuring the increase in load-bearing capacity of extruded layers was developed.

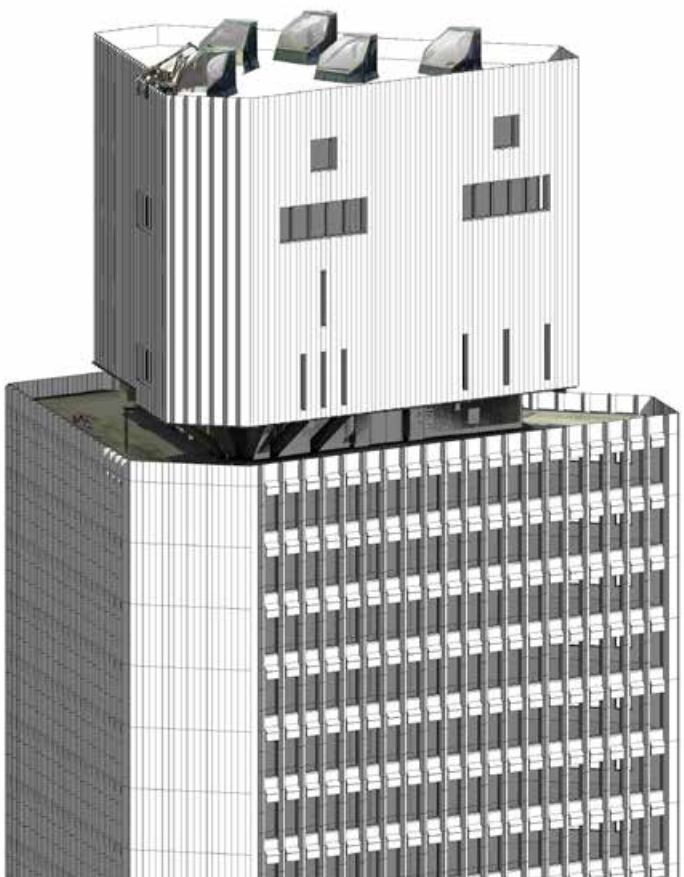
Digital Transformation of Buildings

doc. dr. Katja Malovrh Rebec

Construction is on the threshold of a major transformation, driven by digitalisation. Over the next decade, digitilisation i.e. different technologies and practices that aim to increase efficiency, sustainability and the overall results of projects, will fundamentally reshape the industry. The key trends in digitisation are as follows:

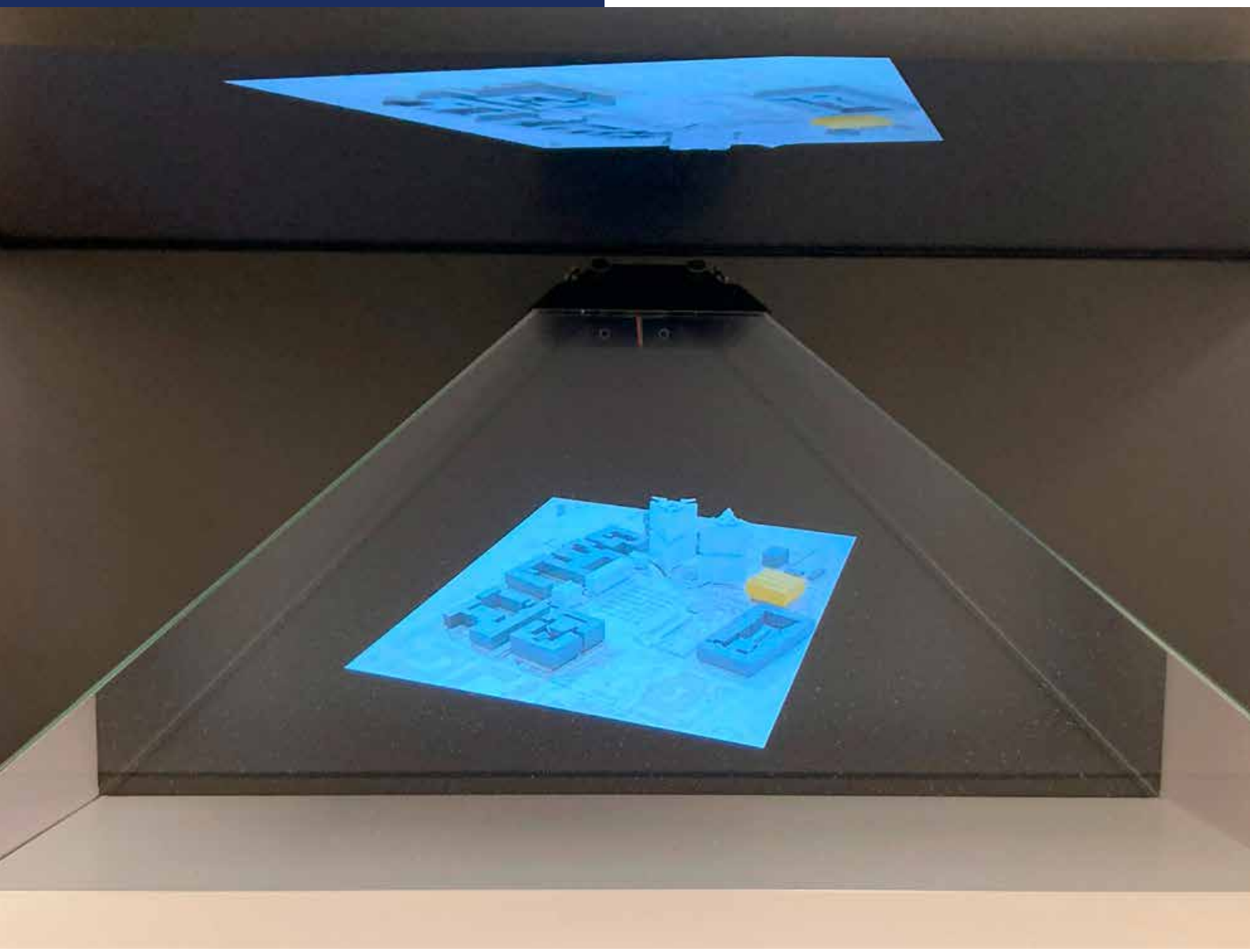
Quality communication through advanced tools

Building Information Modelling (BIM) is a process supported by a range of tools, technologies and contracts that involve the creation and management of digital models to describe the physical and functional characteristics of the built environment. Together with solutions such as the Digital Log Book, the Materials Passport and the Materials Cadastres at City Level, BIM will enable a complete transformation of the construction industry. Better collaboration between architects, engineers, contractors and others involved in the construction process will result in significantly better buildings in the future. We will reduce errors and rework, dramatically increase the efficiency and quality of projects, and achieve a significantly better match between the intended/ modelled performance and the actual performance.



Advanced data capture and analysis, including through machine learning

The Internet of Things (IoT) is already revolutionising construction today by connecting different devices and sensors to collect data in real time. This data can provide alerts and insights to help manage construction sites, existing buildings, and their components (e.g. shading devices, solar power plants) more efficiently. Digital twins, i.e. virtual replicas of physical structures, are also gaining ground. These allow the continuous monitoring of a building's performance, using sensors to monitor various indicators, such as energy use and air quality. In the future, predictive maintenance with feedback loops will bring about a much more transparent and efficient use of resources. The periodic capture of spatial data, point clouds, using laser scanners combined with photometry, where the scanners can be used in conjunction with drones, is also becoming extremely important. Big data cap-



ture, storage, and advanced analysis will become a normal part of building processes. Predictive analytics will also open the door for optimising schedules and decision-making based on actual user needs. The market for artificial intelligence or machine learning in the construction industry is growing in leaps and bounds. The same is true for the data market, which is just getting off the ground.

Growth in robotics and automation

The use of autonomous vehicles and drones to monitor construction sites and deliver materials will become more common, streamlining operations and reducing labour costs. Increasingly, robots are likely to perform repetitive and difficult tasks. We might witness an increase in advanced prefabricated solutions designed with environmental considerations in mind. We will improve the precision of execution,

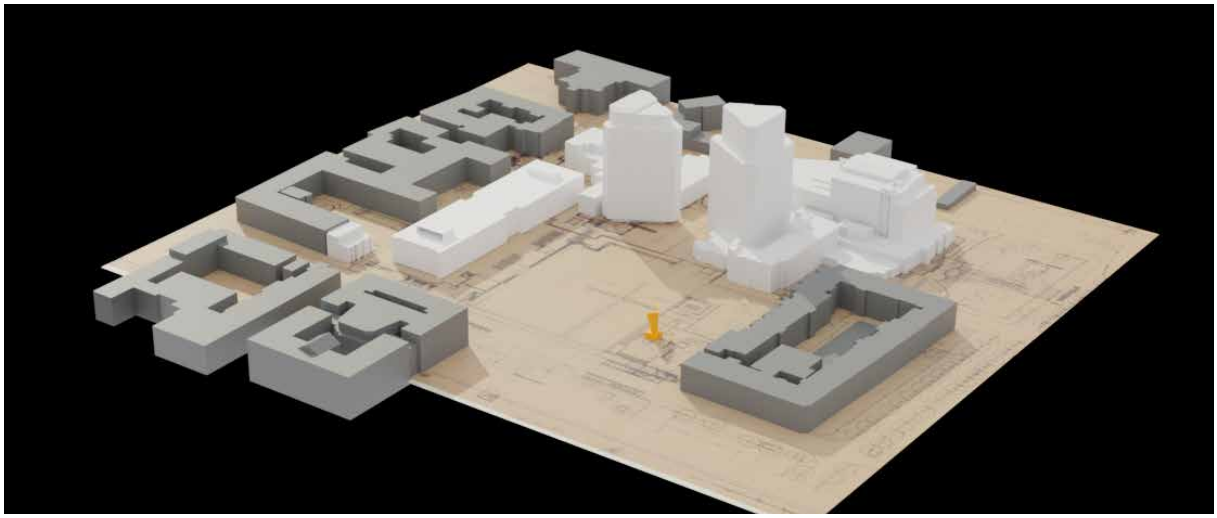
while increasing the safety of workers on construction sites. The use of collaborative robots (cobots) working alongside human workers is particularly promising.

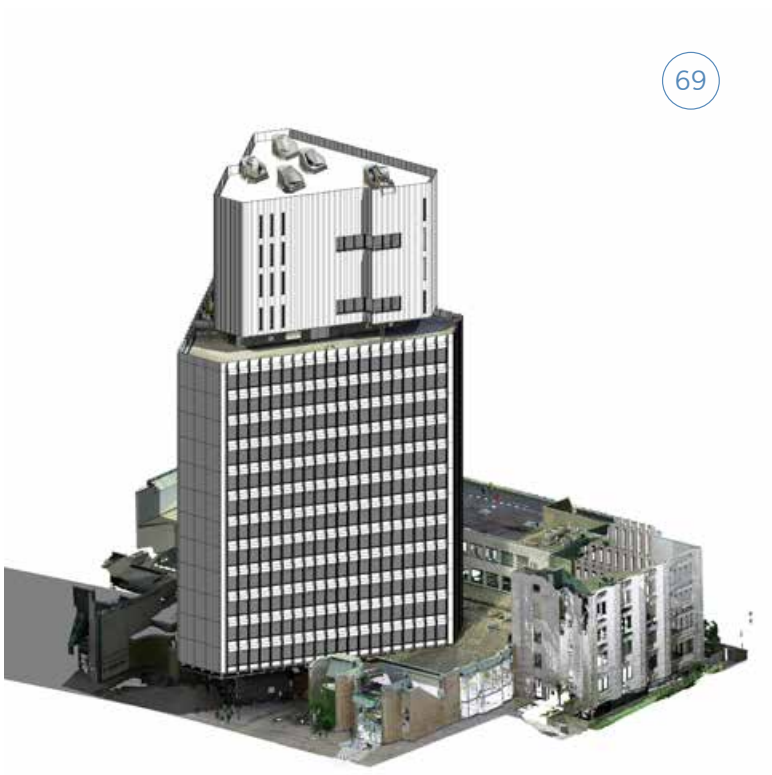
New skills, smart cities and renovations

Modernising the existing built infrastructure is a major challenge, as is updating the skill set of construction sector workers to meet smart city standards. Older buildings and infrastructure may need extensive renovations to incorporate IoT devices, improve energy efficiency and increase connectivity. Construction companies will need to develop specialised expertise in retrofitting. The rise of smart cities in construction automatically means the development of innovation, which will encourage the industry to adopt advanced technologies, prioritise durability and sustainability, and develop new skills. It will, however, also bring a number of challenges.

Digitising human responses

Sensors in buildings are already being used to collect real-time data on users' behaviour, preferences and interactions with the built environment. Sensors can monitor factors such as occupancy levels, temperature preferences, lighting adjustments and even biometric data in order to gain insights into people's responses and their wellbeing or even regulate their emotions. By analysing the data obtained from sensors, buildings can either be designed or upgraded to adapt to individual preferences and needs. Data collected from sensors and feedback from occupants can be analysed with artificial intelligence and machine learning algorithms to identify patterns and optimise building performance. This can then be combined with data collected by other devices, such as smartwatches and ear buds, that measure brain activity, blood oxygen levels, heart rate and user movement. Integration will further improve the prediction of occupancy patterns, forecast maintenance needs and enable recommendations to be made to improve energy efficiency. As the digitisation of people's responses in the built environment involves the collection and analysis of personal data, it is crucial to address data privacy and security issues. Robust data protection measures need to be put in place and clear communication made regarding data use and user consent protocols in order to ensure the responsible and ethical use of this data.





X-ray Computed Microtomography

dr. Lidija Korat Bensa
dr. Miha Hren
dr. Rožle Repič
dr. Alenka Mauko Pranjić
dr. Lucia Mancini

The Slovenian National Building and Civil Engineering Institute is the only research institution in Slovenia that has been working in the field of X-ray computed microtomography for more than 10 years, and the only one that uses this technology in the field of construction materials. The high-tech research equipment in the Department of Materials enables 2D, 3D, and 4D analyses of various materials and their structures as well as changes in their structure depending on time, temperature, or applied stress.

The materials we encounter daily, which are used for a variety of purposes, respond differently to environmental factors such as temperature, humidity, stress, and aging. The mechanical-physical and chemical-mineral processes in materials are extremely important for their properties and performance and also influence their microstructure. In recent years, there has been increasing use of advanced techniques for the observation of microstructure and how it changes. It can be monitored in different ways, and its impact can be determined with various technologies. The observation of microstructure can be used to predict mechanical-physical and chemical-mineralogical processes and properties. One of the advanced techniques used is 3D X-ray imaging. X-ray imaging is an extremely powerful technology that has already been used for years in medical diagnostics and for the quality control of industrial parts. The biggest advantage of X-rays is their ability to penetrate into material, enabling non-invasive imaging and the ability to obtain information inaccessible to either the naked eye or other imaging techniques. The technological significance of X-ray imaging has led to the rapid development of high-performance X-ray detectors and related imaging applications.

X-ray computed microtomography (microCT) is one type of three-dimensional (3D) X-ray imaging technique that allows new achievements and insights in the field of materials, groundbreaking innovations, and development in both science and industry. It is one of the most up-to-date non-destructive methods, enabling researchers and professionals to open up new areas of innovation and development and fostering scientific and innovation excellence. Laboratory X-ray microCT differs from industrial tomography in that it achieves high spatial resolutions (up to a few 100 nanometres). The technology is based on a computer-aided 3D reconstruction of two-dimensional (2D) images (projections) of the sample acquired from different angular views, which are created based on the detection of X-rays transmitted by the sample. The intensity of the beam on the detector depends on the absorption of X-rays in the sample material, which is dependent on the chemical composition of the materials, as well as their density and thickness in the sample.

At ZAG, we have two different instruments. The ZEISS XRadia MicroXCT-400 system has a built-in X-ray microfocus source with the possibility of setting the source voltage between 40 and 150 kV and the power up to 10 W. This robust table allows the analysis of samples up to 12 cm in diameter and approx. 15 cm high, with Verta mass of up to several kilograms. The combination of geometric and optical magnification allows the observation of materials at a spatial resolution of less than 1.0 micrometers, with the final resolution depending on the size and type of the material. The EasyTOM XL Ultra instrument from RX Solutions is a versatile instrument equipped with an X-ray nanofocus source operating between 20 and 160 kV, a maximum power of 32 W and two different detectors: a large flat-panel detector (16-bit, 2560 x 2048 pixels, with an active area of 31.74 x 25.39 cm2) and a water-cooled high-resolution CCD camera (14-bit, 4008x2672 pixels, with an active area of 36x24 mm2). In this device, we can accommodate samples weighing up to 80 kg, with a diameter of up to 730 mm and a height of up to 940 mm. The highest achievable resolution is 0.4 micrometers. The device allows the installation of additional X-ray sources and detectors and, together with the advanced accompanying software, enables use of the most modern scanning methods (e.g. helical CT, laminography, phase-contrast imaging, mosaic CT and dynamic CT). The device can be used with numerous additional modules, such as environmental and mechanical chambers, for in-situ and operando experiments (4D CT), with minimal restrictions with respect to electrical and other connections. A powerful computer allows us to reconstruct and analyze large data sets produced by CT systems such as these. The technical features mentioned above offer us the ability to conduct X-ray imaging and analysis of static and dynamic phenomena, which are important to investigate a number of phenonema, including, amongst others, mechanical failure dynamics, fluid transport properties, the effect of thermal and mechanical treatments or ageing experiments, the impact of the application of consolidant materials, as well as enabling the execution of electrochemical studies.

As well as within the field of construction, the X-ray microCT method is also used at ZAG in mineralogy, volcanology, reservoir rocks, heritage science, energy storage, wood science and technology, pharmacy, biology, sensor technology and dental medicine. The method can be used for the analysis of various materials, and in addition to determining the distribution of different mineral phases or the chemical composition, it can detect various deformations, inclusions, pores, fibers, cracks, and manufacturing

defects that affect the behaviour and durability of a material. Individual components can be analyzed both qualitatively and quantitatively. For image processing and analysis, which allows the separation of individual components/ materials and their spatial and size distribution to be visualized and quantified, we use advanced computer programs working in the 3D and 4D domain, such as the commercial software Avizo Fire (Thermo Fisher Scientific) and Dragonfly (Comet Technologies Canada Inc), and research codes in the Fiji and PyPore3D libraries. With image processing, in addition to individual images, we can export a 3D model in various formats (e.g., raw, tiff, .stl, and .obj), which can then serve as the basis for 3D printing, modeling, the examination of tomographic images, or for determining the deviation of a CT image from an ideal 3D CAD model. After processing, quantitative data can be extracted from the CT data, including the porosity and pore structure (proportion of pores within the material, pore size distribution, pore connectivity), density measurements (variations in density), crack and fiber analysis (volume, length and width, orientation), material composition (phase identification, homogeneity, structural integrity), thermal expansion, and microstructural features (particle distribution, analysis of the interfacial zone, grain structure and pattern analysis).

With the specially-designed Deben 500N HRC chamber (Deben UK Ltd.), we can simulate realistic environments by varying the temperature or mechanical loading of the sample e.g. conduct temporal monitoring of hydration processes in cement or the growth of cracks in concrete under compressive loading. 3D images of the sample are captured before, during and after mechanical loading.The occurrence of changes in the microstructure can be monitored by capturing 2D image cross-sections – the test is then stopped at the point where changes are observed and 3D capture is performed. In addition, we can run experiments in real time and in operando mode using the EasyTOM XL Ultra tomograph. Subsequent image analysis allows us to determine the location of the failure, the occurrence of damage as a function of load or the rate and time of loading. The environmental chamber can be used to monitor, among other things, the deformation of wood in the Brinell hardness test, where a pressure chamber is used to press a ball into the material. The data obtained in such a test not only allows us to accurately measure the deformation, but also shows when and under which conditions (stress, displacement) a particular phenomenon occurs, and - in certain cases - the reasons why the deformation or failure occurred. Such analyses can be used to understand complex changes, as they allow us to observe the situation of failure processes and thus contribute to the improvement of materials.

MicroCT is an indispensable method in other fields as well. As a non-destructive method, it is useful in the digitization of museum artifacts, as samples are not destroyed during the analysis. Some interesting examples we have analyzed at ZAG include the oldest Neanderthal flute from the Divje Babe site, Egyptian amulets from the collection at the Slovenian Ethnographic Museum, rattles from Dežman's pile dwellings, a Paleolithic point from the Ljubljanica, cave bear paw prints in cave sediment, an Enigma cypher machine, and a wooden head of John the Baptist from Bohinj.

We collaborate with various experts from industry. In the development of temperature sensors and electric motors, for example, we compare defects between the product and the CAD model. With dental experts, we analyse damage to pins and dental appliances and create 3D printing matrices for teeth. With biologists we analyse different organisms, such as bees, bugs, crustaceans and plants. With palaeoanthropologists we study human evolution through virtual histological analysis of bones and teeth, and in electrochemistry we collaborate to develop new energy storage devices with reduced environmental impact and improved safety. We also work with artists to visualise artworks. In the field of microtomography, ZAG actively collaborates with national and foreign universities, museums and research institutes, including Agency for Radioactive Waste Management (ARAO, Slovenia), the Ministry of the Interior, the University of Ljubljana, the University of Maribor, the University of Antwerp (Belgium), Politecnico di Milano (Italy), Sapienza University of Rome (Italy), the National Institute of Geology and Volcanology (INGV, Italy), Central European Institute of Technology (CEITEC,Czechia), Federal Institute for Materials Research and Testing (BAM,Germany) and Delft University of Technology (Netherlands). As a reliable and professional partner, we participate in a wide variety of activities, including, amongst others, microCT analyses of various items (e.g. objects damaged in accidents), studying reinforcement in steel for the purpose of nuclear waste storage, replacing lead and bismuth inclusions in aluminum to improve material properties, studying the thickness of thin layers on metal, determining the taxonomy of early Triassic ostracods and foraminiferas, and investigating the ageing behavior of rechargeable Zn-air batteries. We are part of the the Lund Institute for advanced Neutron and X-ray Science (LINXS, Sweden) and European Research Infrastructure for Heritage Science (E-RIHS).

As a non-destructive, high-resolution material characterization tool, X-ray microCT is becoming an indispensable method. With the development of technology and related software tools, including the use of Machine Learning and Deep Learning approaches, the interest and awareness of stakeholders regarding advancements in this field have also increased, and we expect a similar trend to continue in the future. In addition to the benefits mentioned above, microCT enables a 3D insight into the microstructural properties of the object examined, giving access to its external and internal features, which is not possible with other, existing optical methods (with the exception of neutrons, high-frequency, and ultrasound). In addition to laboratory-based X-ray microCT, ZAG researchers are also experienced in other techniques and operate at large-scale facilities such as the Elettra (Trieste, Italy) and APS (Illinois, USA) synchrotron laboratories and the ILL neutron source (France), where X-ray and neutron tomography set ups are available. These imaging techniques and experimental set ups complement each other and allow the best results to be obtained as a function of specific scientific or industrial applications.

Circular Construction

dr. Alenka Mauko Pranjić
dr. Primož Oprčkal
dr. Vilma Ducman

Why circular construction?

Construction is a material-intensive economic sector that consumes more than half of all extracted raw materials in the world. Economic forecasts show an increase in the productivity of the construction sector (e.g. up 35% by 2030), which will further increase the amount of raw materials needed for the construction sector in the future. OECD forecasts show that, by 2060, the global amount of natural aggregate needed as a basic building material will double, to 55 gigatonnes. Ensuring sufficient quantities of materials will be a major challenge for the construction industry in the future, especially given the limited supplies of natural raw materials and the requirements for a reduction in greenhouse gas emissions and decarbonisation of the economy. As a society, therefore, we must work out how to live within the natural limits of the planet, making it imperative for us to look for alternative, more sustainable sources in the form of secondary raw materials, which are created by recycling waste or using by-products through industrial symbiosis. In addition, it is important to ensure the easy decommissioning and reuse of construction products, thereby prolonging their life cycles through the sensible and systematic design of construction materials and the design of buildings and infrastructure. Recently, the development of digital tools in the construction industry has also increasingly contributed to this. Examples of such are tools for increasing traceability and the flow of information e.g. digital product passports and digital logbooks, and the use of building information models (BIM) for the design, construction and management of construction facilities. The use of robotic and automated techniques for the more accurate, faster and safer demolition, renovation and construction of buildings is also increasingly present.

How to put construction products based on secondary raw materials on the market?

Construction products from secondary raw materials, i.e. from recycled waste or by-products, must meet the regulatory requirements of environmental legislation with respect to terminating the status of waste or -products, and must be placed on the market under the same conditions as products made from primary raw materials. They must meet all the requirements for properties that affect the basic requirements of construction works, according to their intended use, in accordance with European and national legislation and regulations on construction products and construction. In 2024, we actively contributed to the preparation of legislation concerning the creation of conditions for terminating the status of certain waste products suitable for processing and subsequent use in the construction industry, and we are also following changes in legislation at the European level - such as proving the seventh basic requirement for construction works, for example, which calls for the sustainable use of primary raw materials in the construction industry, with Life Cycle Assessment (LCA) tools, where the use of local secondary raw materials can have a significant impact on reducing the environmental impact of buildings.

New technologies and new materials from secondary raw materials

At the Slovenian National Building and Civil Engineering Institute, we have been actively working for many years on the development and use of new construction products made from secondary raw materials. A good knowledge of the microstructure, mineral composition, chemical processes and physical properties of various wastes and by-products, as well as that of the final products, is key here. We always try to close material loops locally, using simple, sufficiently-robust and efficient processing procedures with the lowest environmental footprint that can provide technically adequate and environmentally-acceptable construction products in sufficiently large quantities. Such products can replace conventional products made of natural and artificial materials. When processing different types of waste, or using by-products for construction purposes, we must also be careful not to release substances that are potentially dangerous to the health of people, animals or the environment.

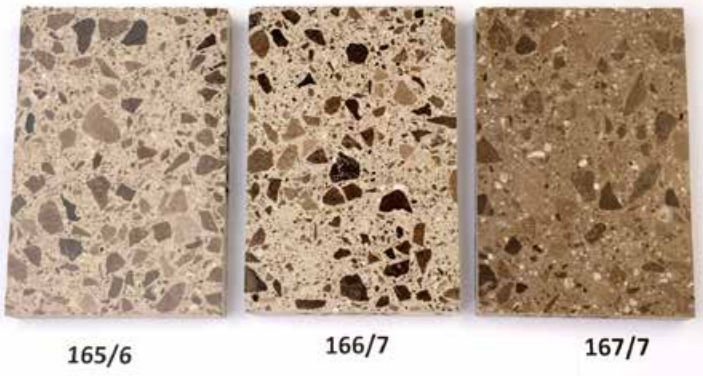
Using our experience, the advanced analytical methods available at ZAG, and in-depth knowledge of the properties of these materials and recycling processes, we can ensure that the final products will be safe and technically usable once they are put on the market. Over recent years, we have gained new

experience in the effective management of material flows e.g. in the selective elimination of high-quality materials from those with inadequate physical properties in relation to their intended use, especially through cooperation in major projects related to (transport) infrastructure. We are developing and improving a number of construction products from secondary raw materials. A few examples of those we are currently researching include recycled aggregates from the processing of construction and demolition waste, manufactured aggregates from the processing of waste or by-products generated from thermal processes in metallurgy (e.g. slag, foundry sands, ashes), alternative hydraulic and/or pozzolanic binders in the form of geotechnical composites with calcium-rich ashes, used as substitutes and additives for Portland cement in hydraulic/ pozzolanic bound soils and cement composites, additives from secondary raw materials for asphalts, and geopolymer composites or alkali-activated materials as an alternative to concrete. We place great emphasis on the research and development of construction products with carbonation processes. Materials based on steel slag, certain ashes or recycled concrete are rich in calcium minerals and, under certain conditions, permanently bind CO_2, meaning they can contribute to the decarbonisation of the construction sector. Products of this type can be used for earthworks or to produce concrete prefabrication units, pavers and bricks. In addition to new materials, we are also developing various green technologies e.g. for the treatment and reuse of wastewater, technologies for the treatment of hydrometallurgical waste and the enrichment of economic compounds, as well as processes for the immobilization of heavy metals and other pollutants in the soil. We also pay special attention to cascade or sequential recycling, with the prior elimination of valuable and/ or critical raw materials (e.g. phosphorous from the value chain of

municipal wastewater), allowing the residues to be processed for other uses following extraction, e.g. in the construction industry. Important new technology that we are developing in this field is the so-called bioleaching of critical raw materials from various wastes with the help of bacteria and the bioremediation of contaminated soils or other materials.

What about environmental labelling and verification?

New environmental technologies have the potential to successfully verify environmental claims based on the ISO-standardized procedure 14034 for Environmental Technology Verification. In 2024, we completed the European LIFEProETV project, the results of which are gradually being transferred to ZAG services i.e. in addition to being the authority for awarding type III Environmental Product Declarations (EPDs), we are introducing procedures to also become an authority for the verification of environmental technologies. Our experts and scientists are present in the creation of new guidelines and standards in the field of testing and evaluating environmental technologies and products in the construction industry, e.g. on the TC CEN 350 technical committee, 'Durability of Building Structures'. With our knowledge, we can also help companies with sustainable reporting, according to the newly-created European Directive EU 2023/2772, and we also participate in the creation of new regulations and legislation in the field of circular construction.



What are our next steps?

There is considerable potential for research and development in circular construction, including new binders based on secondary raw materials; more durable and sustainable products, with a zero or even net-negative carbon footprint; effective environmental technologies, both in terms of the identification and selective extraction of valuable and/ or potentially hazardous raw materials, as well as the remediation of contaminated soil; the development of knowledge and new methods for monitoring the status of water, soil and air pollution; the use of biomaterials (e.g. residues from agriculture) in construction, modular construction, the reuse of materials, and improving the traceability of materials. These are just some of the topics we will continue to research in the future. On the basis of their knowledge and experience in the field of materials (primary and secondary) and on chemical, mechanical and physical processes, as well as through active cooperation with stakeholders both at home and around the world, our experts successfully support a more sustainable construction sector in Slovenia and help towards a successful green transition, establishing stable, safe and reliable material supply chains and a final market with clearly identifiable components of sustainability.

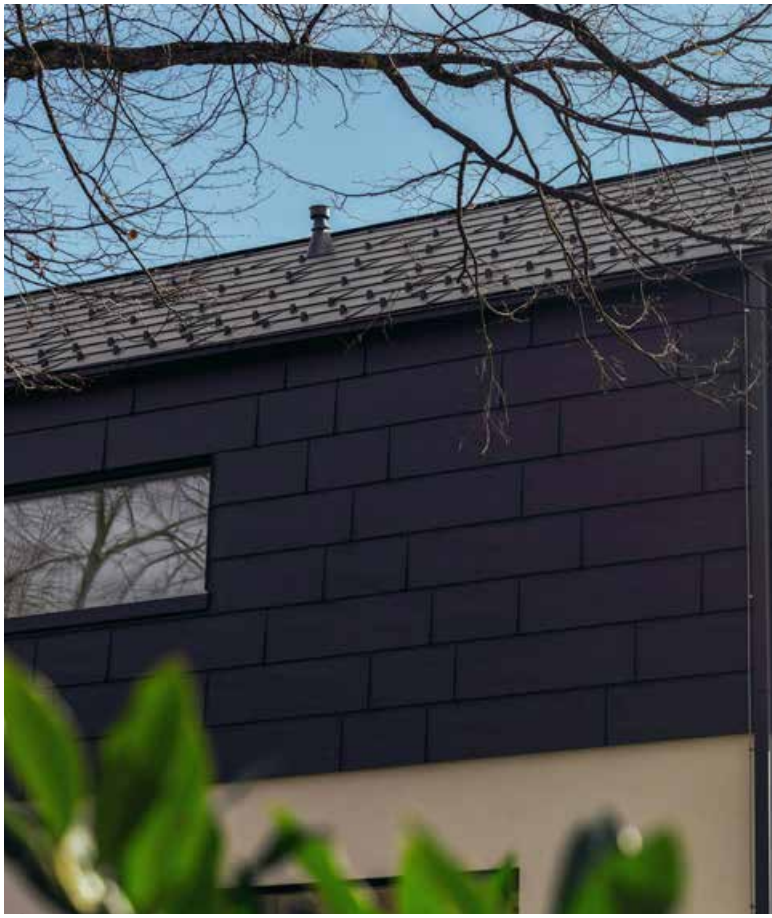
Further important projects in the field of circular construction	
ARIS J7-50228 (ARIS, 2024–2027, ZAG coordinator)	Mining the technosphere for efficient use of resources and improving state of the environment
ReBuilt (Interreg Central Europe, 2023–2026, ZAG coordinator)	Circular and digital renewal of central Europe construction and building sector
LIFE IP RESTART (LIFE, 2022–2030, coordinator MOPE (SI), ZAG partner)	Boosting waste recycling into valuable products by setting the environment for a circular economy in Slovenia
VIRIDI (Interreg Slovenia - Austria, 2023–2026, coordinator Chamber of Commerce of Carinthia (AT), ZAG partner)	Enhancing joint transition to circular and resource efficient economy through holistic and digital support of SMEs in cross border region SI-AT.
LIAISON (Horizon Europe, 2023–2027, coordinator TECNALIA (ES), ZAG partner)	Lowering transport envIronmentAl Impact along the whole life cycle of the future tranSpOrt iNfrastructure
CO2TREAT (ERAMIN, 2022–2025, coordinator VITO (BE), ZAG partner)	Accelerated CO_2 treatment of alkaline residues for low carbon binders
ASHCycle (Obzorje Evropa, 2022–2026, koordinator Univerza v Oulu (FI), ZAG partner)	Integration of underutilized ashes into material cycles by industry-urban symbiosis
ARIS N2-0320 (2023–2026, ZAG coordinator)	Waste to alkali-activated binders (WIN)
ARIS J1-4413 (2022–2025, ZAG coordinator)	Study on hydraulic characteristics of ashes from various thermal processes and the enhancement of the reactivity for their use as an immobilization additive
ARIS J1-3029 (2021–2024, ZAG coordinator)	Holistic sustainability evaluation of critical raw materials - closing gaps and developing new methodological approaches
ARIS L7-3185 (2021–2024, ZAG coordinator)	Investigation of interconnected processes for sustainable management of sewage sludge for the purpose of its material recovery and recycling
LIFEProETV (LIFE, 2020–2024, coordinator IETU (PL), ZAG partner)	Promotion and implementation of ETV as an EU voluntary scheme for verifying performance of environmental technologies
EIT RawMaterials, RIS, WEEE-NET9 (2022–2024, ZAG coordinator)	Improving CRMs extraction capacities in RIS WEEE recycling
EIT RawMaterials, RIS, EPICENTER (2024–2026, coordinator Riga Technical University (LT), ZAG partner)	Educational Platform lIfe Cycle assEssmeNt sTRucturEs
LIFE HIDAQUA (LIFE, 2019– 2025, ZAG coordinator)	Sustainable water management on high water demanding industries
EIT RM GEORIS (EIT RawMaterials, 2022–2024, coordinator ENALOS (GR), ZAG partner)	Innovative technologies for waste processing in ESEE Region

Smart Buildings and Home with Wood Chain

Martina Murko Gajšek
doc. dr. Sabina Jordan

A living and working environment for the future that is sustainable, healthy, environmentally- and user-friendly, connected and energy self-sufficient - based on Slovenian knowledge and industry. This is the vision of the Strategic Development and Innovation Partnership, Smart Buildings and Home with Wood Chain - SRIP PSiDL.

Slovenia is home to several strategic innovation and development partnerships that bring together companies, research organisations, the government and municipalities alongside integrators, users and non-governmental organizations. These partnerships organise a development and innovation ecosystem aimed at penetrating the global market and follow the priority areas of the Slovenian Smart Sustainable Specialisation Strategy, S5. One of the SRIP partnerships, Smart Buildings and Home with Wood Chain, operates within ZAG in co-operation with two consortium partners - the Association of the Wood and Furniture Industry at the Slovenian Chamber of Commerce and Industry and the TECES innovation cluster.



Goals and vision

The SRIP PSiDL partnership is based on the focus areas "construction of buildings", "interior elements", "building supply and management, including connectivity with smart communities" and "smart, nearly zero-energy buildings". Through these focus areas, the project engages Slovenian manufacturers of materials and solutions for construction industry, manufacturers of interior elements and manufacturers of devices, systems and services that enable building management based on user requirements, as well as manufacturers and other stakeholders involved in innovative design and planning.

Through the SRIP PSiDL, we are therefore realising our vision to establish a lasting partnership that enables the development of comprehensive solutions for building a smart, sustainable, healthy, environmentally- and user-friendly, connected and energy self-sufficient living and working environment for the future, based on Slovenian know-how and production.

Our aim is to create an open, operational and rapidly adaptable support environment that, by connecting and creating synergies, will stimulate companies and other stakeholders to achieve high productivity and successfully commercialise competitive products and solutions in the field of smart buildings in both the European and global markets.

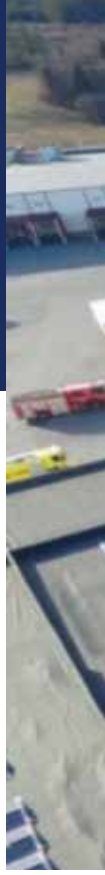
Comprehensive support for business and industry

The vision and objectives of the SRIP PSiDL are further confirmed by its renewed Strategic Plan. This gives the partnership an even clearer focus on strengthening the support environment for the members of SRIP PSiDL. As part of the strategic plan, the partnership aims to continue and build on projects such as the planning and development of Home24h, which has been a successful project in previous phases of SRIP PSiDL. The partnership is involved in the development of demonstration buildings, wooden buildings and pilot projects to validate technology. It invites members to participate in its activities as much as possible, providing a platform for them to expand their own activities. SRIP PSiDL also provides its members with a network of relevant and up-to-date information and professional events in their individual field of activity.

The PSiDL SRIP is made up of 67 organisations. This includes companies, public and private institutions and associations. Membership brings active participation in a number of areas, including shaping the country's development focus and future investments, contributing to joint product development and sharing a joint presence in domestic and foreign markets, establishing and strengthening supply chains, integrating products and rationalising supply chains, conducting joint demonstration projects, establishing new business models and marketing strategies, and providing support for internationalisation, entrepreneurship and the development of human resources.

Fire Safety of Solar Power Plants

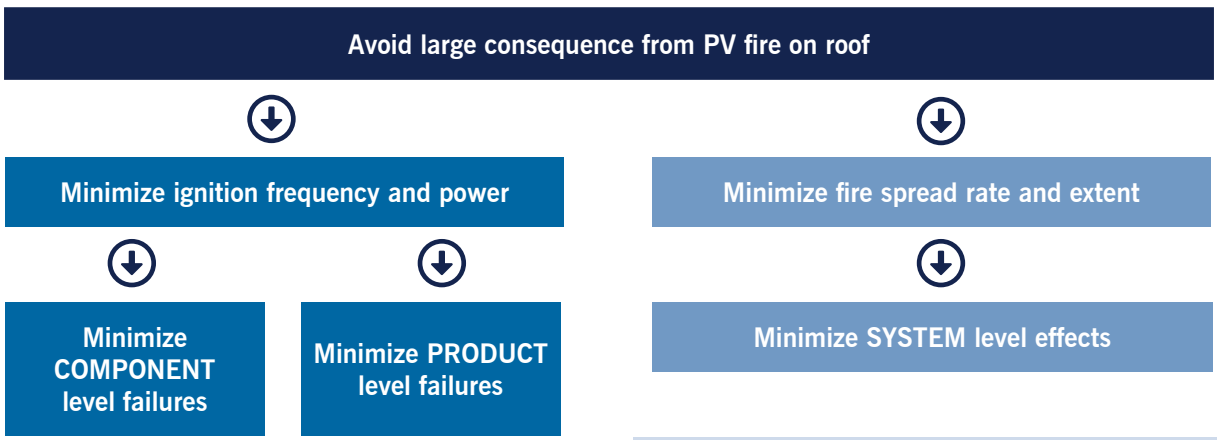
Nik Rus



Photovoltaic (PV) systems are proving to offer an affordable and quick way of moving away from carbon-based fuels as an energy source, especially considering the sustainable goals being encouraged globally. Their installation on the roofs of buildings, however, inevitably brings new fire risks. The risk to the building on which a PV system is installed is greater, due to both the increased likelihood of ignition and the more severe negative consequences of PV-related fires. The increased probability of ignition results from the potential failure of any of the numerous electrical components of the PV system. The negative consequences are exacerbated by the fact that the fire department's work is hindered and that a PV system on a flat roof enables the fire to spread both faster and over a larger area.

A group of researchers from the Fire Research and Innovation Unit at the Department for Fire-safe Sustainable Built Environment (FRISSBE) have identified the gap in assessing the overall risks of PV systems and published a rooftop PV guideline aiming to highlight it. Some existing standards and regulations already address risk mitigation at the material and product level, but there is a need to consider the risks that emerge at a system level when all the materials, parts and products are fully assembled. To illustrate the gap in risk assessment, a fire safety concepts tree has been designed (a simplified version is shown in the scheme below). The left-hand side represents the parts that are already covered, to a certain extent, by various regulations and standards for products and components of PV systems. In contrast, the right-hand side corresponds to what has not yet been considered sufficiently to prevent and mitigate the negative consequences of PV-related fires.

For safety measures to be implemented effectively, they must be based on sound scientific evidence, in the form of either experimental or statistical data. The published guideline is based on the latest scientific findings and supported by in-house experiments conducted for clients and internal projects, involving experiments with various scales, materials, parts, and geometries.



Results have shown that, in the case of fire, the materials of roof membranes and the type of PV panels play less of a role than the geometry of the system and the type of insulation materials used. Wherever the PV panels were mounted at an inclined angle, the fire was able to spread across the entire roofing area below the installed panels and caused an extensive heat load on both the roofing material and the system.

These outcomes prove that systemic aspects, such as the panels' geometric orientation, the size of the arrays, and the distance between them, play an important role in the behaviour of PV-related fires. This research study forms a solid scientific basis for the development of robust solutions for PV systems that are better prepared for fires in the future. In addition to the use of appropriate materials, implementing good installation and maintenance practices is crucial for risk reduction, with the quality and design of the roof structure being the other cornerstones for reducing the consequences of fire and improving firefighter safety.

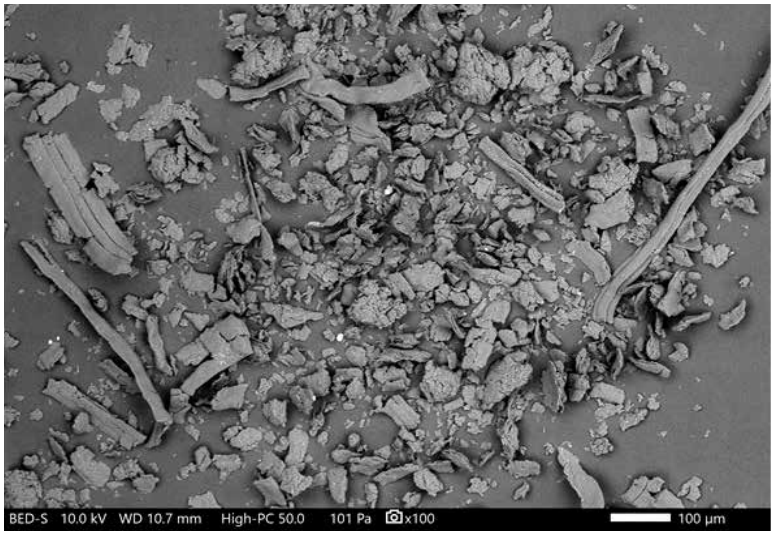
Manipulating Microplastics for a Sustainable Future

doc. dr. Branka Mušič

ZAG is constantly developing, as it is committed to the advancement of knowledge and addressing contemporary social issues, where one of the current focuses is also the environmental challenge of microplastics. By investing in research and innovation, we aim to develop sustainable solutions to mitigate the impact of microplastics on our environment.

The management of plastic waste is a global challenge for researchers, policymakers, citizens, and other stakeholders. Environmental factors, such as changes in temperature, UV radiation, and abrasion, cause plastic waste to degrade into smaller particles (micro- and nanoplastics), which pose a threat to all forms of life. The rapid production and accumulation of plastic in the natural environment results from its indiscriminate use, inadequate recycling, and subsequent disposal of such material in uncontrolled landfills. Consequently, microplastics are leaking into terrestrial and aquatic ecosystems at an alarming rate. The image on the right shows waste plastic products that can weather under environmental conditions to form microplastics (scanning electron microscope image).

ZAG addresses the social challenges regarding the pollution of natural ecosystems with micro- or nanoplastics through national and European research projects. These initiatives support a higher rate of recycling of plastic waste and promote a circular economy. Such are, for example, "Returning waste insulating polyurethane foams to composite facade panels" and "Incorporating recycled waste rubber into geopolymer composite pavers" earned the silver award from the SRIP (The Strategic Research and Innovation Partnership) for the Circular Economy. In



the picture on the next page, you can see alkaline-activated metakaolin-based pavers with rough-cut rubber waste incorporated into the walking surface.

By reusing waste polyurethane foam and waste rubber, which, at the end of their life cycle, often end up in landfill, where they degrade into microplastics or await incineration, we have eliminated one potential source of microplastics.

We are aware that the formation of microplastics cannot be avoided completely, which is why ZAG clearly emphasizes the importance of understanding the development of ecologically acceptable (polymeric) materials, as well as the importance of evaluating the formation of microplastics from plastic - including the use of artificial, accelerated aging techniques. We employ advanced analytical methods to characterize (micro)plastics and mechanical, physical and chemical changes in the properties of polymer matrices, including changes in the size and shape of particles, the density, thermal response, hardness and cleavage of chemical bonds, and the leaching of pollutants from microplastics. We are proud of our cooperation with esteemed Slovenian institutions, including the Biotechnical Faculty and the Faculty of Chemistry and Chemical Technology, with whom we also collaborate in this field in assessing the impact of microplastics on living organisms, according to established standard methods.

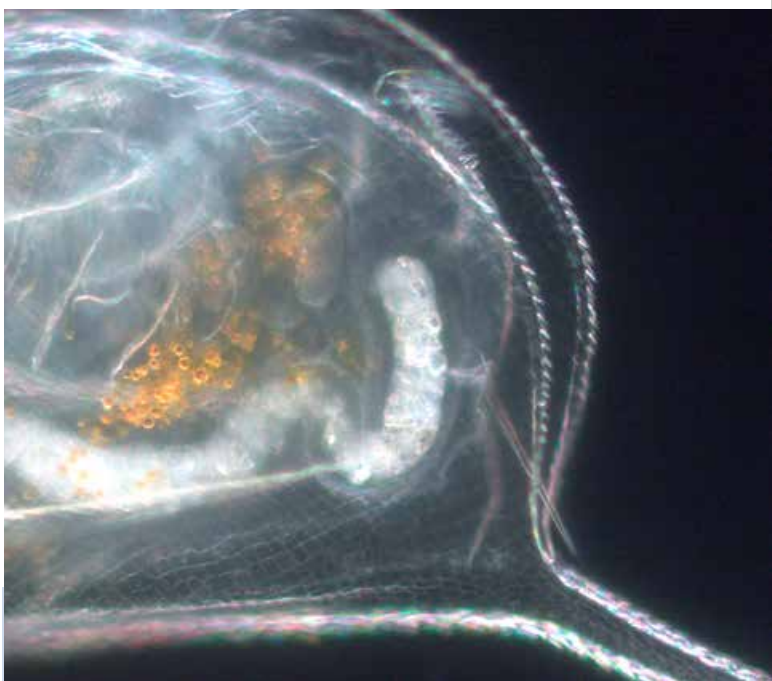
Achievements in the form of publishing scientific articles are also considered successes. In collaboration with our partners, we disseminate the results of original scientific research to the public, addressing current issues while they are still in their early stages. During the COVID-19 pandemic, for example, we investigated the impact of the drastic increase in the use and disposal of protective masks on the environment. Our article, "Environmental hazard of polypropylene microplastics from disposable medical masks: acute toxicity towards Daphnia magna and current knowledge on other polypropylene microplastics," explores the environmental impact of microplastics from medical masks as a new source of environmental burden. Shown below are representative light microscope images of a large water flea (Daphnia magna) after 48 hours of exposure to medical mask microplastics. The image on the left shows microplastic from the middle filter layer of a medical mask attached to the body surface of D. magna, while the right image presents microplastic from the inner frontal layer of the medical mask in the gut of D. magna (doi: 10.1186/s43591-021-00020-0). This research revealed that plastic microparticles are entering the food chain, raising significant concerns about their long-term effects.

ZAG is also one of the leading promoters of awareness about microplastics in the construction sector. We actively co-create care for nature by connecting with other experts and forge long-term partnerships, through which we promote progress and understanding and as such co-create a cleaner living environment, as policy makers often rely on findings reported in scientific papers.

In 2024, the ZAG team will be further strengthened in this area by an excellent young researcher, with the aim of consolidating a key role in our socially beneficial and socially responsible initiatives. This will not only advance engineering practices, but also contribute significantly to the well-being of the community.

ZAG is aware of the need to raise awareness and educate the entire community, encouraging them to help reduce (micro)plastic pollution and use alternatives to plastic. Addressing (micro)plastic pollution is a global challenge that must be prioritized, requiring collective action across all sectors.

Thank you to everyone who has previously contributed to our efforts in advancing microplastics research, to those involved in our current and upcoming projects, and to everyone who trusts and supports us.



200 Years of Cement

doc. dr. Sabina Dolenec
Ana Brunčič
Lina Završnik

This year marks the 200th anniversary of the patenting of Portland cement, which was introduced to the world on October 21, 1824 by the British patent BP 5022, 'An Improvement in the Mode of Producing an Artificial Stone'. The invention had a great impact on modern society.

Ordinary Portland cement (OPC) is the most common type of cement used worldwide, as the main component of concrete as well as in some other construction products, such as mortars and grouts. Portland cement did not become the most widely used material on Earth by accident. Cement is basically composed of oxides of silicon, aluminum, iron, calcium, sodium, potassium and magnesium, which make up more than 98% of the Earth's crust. This enables us to produce cement almost anywhere in the world, using raw materials available locally. Fundamentally, minerals containing other elements are not available in the quantities necessary to meet the global demand for cementitious materials. The

first cement plant in our region opened in Trbovlje in 1876. It was one of the first cement plants in Europe and was built at almost the same time as the first cement plant in the USA (1871). In 1921, the cement factory in Anhovo also started production. In the past, there was another cement factory in Slovenia, operating in Dovje/ Mojstrana, which started producing cement in 1893. The consumption of cement is closely related to the economic development of a region or country.

Cement both enabled and caused the evolution of construction, replacing bar steel and wooden structures consisting of a multitude of joined elements with concrete, which can be cast. The dominance of the use of cement materials in the construction industry began in 1880. With the invention of reinforced concrete (1984), and later prestressed concrete and concrete and steel composite structures (1930), concrete only consolidated its position as the leading construction material. Concrete was resoundingly presented as a modern material through the works of the French architect, Le Corbusier, who was a pioneer of the modern movement of the 20th century. The range of use of cement-based materials and concrete in Slovenia can be detected after the earthquake in Ljubljana in 1895, when a new craft appeared in 1886 - namely the production of artificial stone and concrete products, which were significantly cheaper than natural stone. Concrete, in cooperation with built-in iron arch supports, was the basic construction material used for the Dragon Bridge, built in 1901, which is said to represent a turning point in the evaluation of concrete in terms of its visual appearance. In the Ljubljana region,

concrete only became established as an material equivalent to stone between the two world wars, when, in particular, it was used for bridges designed by the architect Jože Plečnik. It is worth highlighting that the works of Plečnik, in which he used concrete as building blocks, were entered into the UNESCO World Heritage List in 2021.

Cement plays a vital but often overlooked role in modern day-to-day life. It is mainly used as a binder in concrete, which is the second most-used material on Earth (after water), and is the primary material used in the infrastructure for most human activities. It is a versatile and reliable building material with a wide range of uses. In addition to the use of cement for the production of concrete, where it represents between 10 and 15% of the volume, cement is also used in mortars for masonry structures, plasters and injection grouts, as well as for soil stabilization.

The Laboratory for Cements, Mortars and Ceramics at the Slovenia National Building and Civil Engineering Institute - the only laboratory of its kind in Slovenia - is dedicated to the study of cements, the development of new mineral binders and the testing of cements and cement-based materials (adhesives, grouts and mortars). The quality of cement is important and fundamental for active construction works, so we carry out chemical and physical-mechanical testing of cement in the laboratory for the purposes of certification and production control, while the experts of the laboratory also act as authorized persons for the certification of cement and cement-based products and as leading experts for technical evaluations and consents. The laboratory has been accredited according to ISO EN/IEC 17025 since 2001. From 2009 to 2023, the laboratory was appointed by the Bureau of Metrology as the holder of the national standard for the field of bulk substances in cements and was a member of EURAMET – the European Association of National Metrology Institutes. Between 2004 and 2020, we were involved in the international association NanoCEM - an industrial-academic network for cement and concrete research, which brought together the most important European institutions in the field.

Within our work, we primarily investigate and study types of cement from the OPC family and calcium aluminate cements (CAC). In recent years we have also been developing new low-energy and low-carbon cement clinkers and cements. We study the chemical processes of cement hydration, the influence of min-

eral and chemical additives on the hydration of cement minerals, cements and mortars, the chemical resistance of mineral building materials to aggressive media, the penetration of chloride ions into mortars and concrete, and more. Over the 75-year history of ZAG, the laboratory has developed, amongst other things, expansion cement for Slovenian hydroelectric power plants and an additive to prevent shrinkage in potting compounds used for prestressing cables. We deal with the use of secondary raw materials for construction materials and products. We also work in the field of cultural heritage.

Compared to other construction materials, cement is a sustainable material, as it has low energy and low carbon footprints - the problem is mainly caused by the sheer amount of cement produced, as we use over 10 times more of it than any other building material. For some time, development in the field of cement has been strongly focused on reducing the carbon footprint, which is mainly achieved by using locally-available non-carbonate secondary raw materials, by replacing the clinker in cement with mineral additives, or by developing alternative binders that are prepared by partially replacing conventional OPC clinker or by removing it altogether. The use of mineral additives, many of which are also secondary raw materials, both allows the acquisition of a sustainable binder and contributes to a circular economy. A large part of research in the laboratory over recent years has focused on the development of alkali-activated binders and subsequent construction products, as well as new types of cement clinker or cements, such as belite-calcium sulphoaluminate cement. All these cements have their advantages and limitations, the latter primarily being the (lack of) availability of raw materials for wider production. As a result, such cements tend to have limited use, or exhibit special properties not comparable to OPC, thus further limiting their application. When investigating the use of secondary raw materials, it is particularly important to consider the leaching of toxic substances from products. For this purpose, we are also developing procedures to determine the concentrations of elements in leachates, using the inductively-coupled plasma method (ICP). Recently, however, we have also been devoting ourselves to the development of one of the more promising new types of cement, LC3, which is achieved through the addition of calcined clay and fine limestone in place of the clinker. In this light, we are researching the reactivity of various clays from sites around Slovenia, developing cements with this mineral additive and studying the carbonation processes of these cements. Cement and/ or cement-based materials can also represent a large reservoir for capturing carbon, hence certain studies also focus on the possibility of carbon sequestration and carbonation processes. This has the added benefit of improving the properties of some waste materials, e.g. calcium ashes and steel slag, which, until now, were not suitable for use as mineral additives for cement.

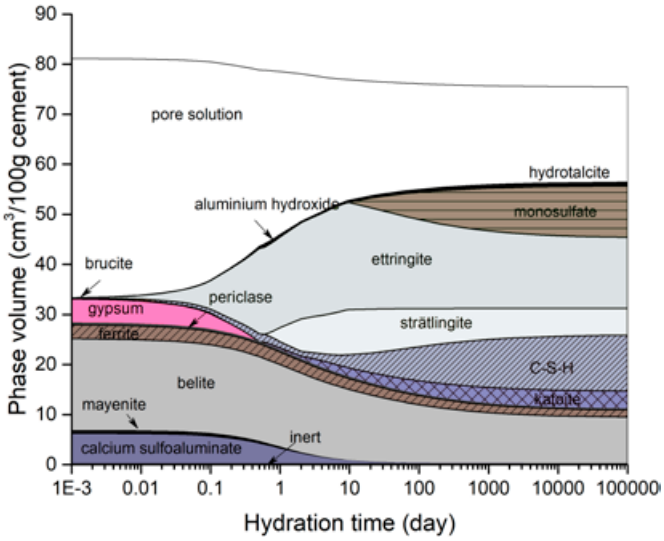
In the laboratory, we determine the composition of unhydrated cements and study the course of hydration and the formation of hydration products, as well as the microstructure of cements and cement-based products. We use a variety of advanced analytical techniques, including X-ray fluorescence spectroscopy, X-ray powder diffraction analysis and the Rietveld method, Raman microspectroscopy, thermogravimetric analysis and scanning electron microscopy with EDS, while pore development can be determined by mercury porosimetry and gas sorption, as well as computed microtomography. In order to explain the mechanisms of hydration, we are also developing a method for extracting and determining the chemical composition of pore water. The use of thermodynamic modeling in cement systems is also key, as it allows parameters to be changed quickly and easily, enables the composition

of groups of hydration products to be predicted under different conditions, and can be extrapolated to represent longer periods of time, which also helps in experimental studies.

Among other things, cement is also one of the most widespread materials that comes into contact with drinking water. For visual and hygienic reasons, and to protect the concrete, cement-based materials or the products are used as coatings in reservoirs, where they remain in constant contact with water. We participated in the preparation of a guidance document, 'Recommendations for evaluating the suitability of materials and products that come into contact with drinking water', according to which it is also possible to certify metal, cement, organic and combined materials that come into contact with drinking water.

Cement is also important in the immobilization of low and medium radioactive waste. We are involved in EURAD 2 – the European Partnership on Radioactive Waste Management – which is concerned with the innovative and sustainable design, optimization and upgrade of processing and conditioning materials for the preliminary disposal of problematic waste. As part of the project, our team participates in the production of materials for the construction of a repository for low- and medium-level radioactive waste (NSRAO).

With the development of new technologies, such as 3d printing, the study of the properties of cements in their fresh state - including the consistency, cohesiveness, workability and setting time - is at the fore. This can be achieved using isothermal calorimetry and rheometer methods, amongst others. Early hydration involves complex chemical and physical processes that control the behaviour of fresh concrete, concrete setting and hardening, and also affect the mechanical properties and durability of the final product. In cooperation with the Laboratory for Concrete, we are studying the influence of various



mineral additives on the fresh properties of cement mixtures, the influence of temperature on the cohesiveness of cements in the early stages of hydration, and active control of the rheological properties of cements with magnetic particles, which would be useful for moving the material.

Additionally, we contribute to the development of biomineralization processes - as a biologically-inspired and sustainable approach to the preservation of cultural heritage and the self-healing of cementitious materials. In connection with the Biotechnical Faculty of the University of Ljubljana, we are investigating the self-healing ability through microbiologically-induced precipitation of calcium carbonate in the cement matrix, with a particular focus on the study of alkali-tolerant extremophilic fungi suitable for this purpose.

Finally, we are active in several national and international associations, including the Slovenian Institute for Standardization (SIST) - Mineral binders and masonry, and various technical committees of RILEM, where we are currently part of the following committees: PHC (Performance testing of hydraulic cements), EBD (Performance testing of hydraulic cements), UMW (Upcycling Powder Mineral "Wastes" into Cement Matrices), PFC (Performance requirements and testing of fresh printable cement-based materials) and MPA (Mechanical properties of alkali-activated concrete).

External Quality Control

Laura Vovčko
dr. Borut Petkovšek

The Unit for External Quality Control of Works and Materials connects various departments. Our purpose is to align the scientific and professional knowledge of ZAG researchers with the needs of the country, striving for high-quality construction in the most important infrastructure projects.

As an independent body and the largest construction institution in Slovenia, we verify the quality of construction products, such as concrete products, steel products and wooden or concrete sleepers. With the installation of materials, we also pay attention to potential impacts that could cause the accelerated degradation of materials, consequently shortening the lifespan and usability of structures. By visiting construction sites, we check the execution of construction works, the competence and equipment of construction contractors, and, above all, the operation of their internal quality control. By performing quality control, we promptly identify irregularities and thus crucially contribute to the sustainability and long life of structures.

We provide clients with professional support in all areas of construction, offering advice on how to resolve various technical problems. Our professional support is most effective when we are involved in the project in a timely manner and where communication is established between all participants involved.

Our work began in 1994, with the start of the construction of the highways (which is still ongoing, and continues with the renovation of highways and expressways), and has since expanded to include the major sections of state roads. We are now also engaged with quality control in the construction of earth and concrete dams, in the construction and reconstruction of railway connections in our country, and in other infrastructural projects of special importance - such as signal transmitters for railways (GSMR) and telecom systems, TE Šoštanj, the Slovene disposal site for low and intermediate-level radioactive waste, Brnik Airport, and the Port of Koper, amongst others.

We procure our work through the private sector, relating academic knowledge - acquired at universities and enhanced through participation in international

research projects - with the needs of the state and its agencies, administrations and companies.

Currently, we have ongoing work within the following major infrastructure projects:

- Construction of the 2nd railway track between Koper and Divača,
- Construction of the second tube of the Karavanke tunnel,
- Construction of all sections of the expressway in the northern part of the 3rd Development Axis,
- Both construction and reconstruction at the Maribor–Šentilj and Brezovica–Borovnica railway sections,
- Construction of the waste disposal site for low and intermediate-level radioactive waste from the Krško Nuclear Power Plant, and a storage site at Brinje, where the Triga reactor operates.

The vision of the unit is to maintain ZAG's leading position for external control in Slovenia, deepen cooperation with major investors, and expand our activity to other segments of construction, such as special waste disposal sites, transmission lines and underground storage, the construction of the 2nd block of the Krško Nuclear Power Plant and residential construction.

Technical Observation of Barriers

dr. Pavel Žvanut

At the Slovenian National Building and Civil Engineering Institute, we perform technical observation or monitor the behaviour of the following large dam structures in Slovenia:

- all 10 concrete hydroelectric dams on the Drava River (Dravograd, Vuzenica, Vuhred, Ožbalt, Fala, Mariborski otok, Melje, Zlatoličje, Markovci and Formin), for the company Dravske elektrarne Maribor
- 5 concrete hydroelectric dams in the Sava River basin (Završnica, Moste, Mavčiče, Medvode and Vrhovo), for the company Savske elektrarne Ljubljana
- all 3 concrete hydroelectric dams on the Soča River (Ajba, Podsela and Solkan), for the company Soške elektrarne Nova Gorica
- the Vogršček embankment dam, for the company Hidrotehnik

As part of the technical observation, both regular and extraordinary inspections and measurements are carried out. The latter are performed after high water levels and stronger earthquakes.
Visual inspections, which, in recent years, have been assisted by drones, include:

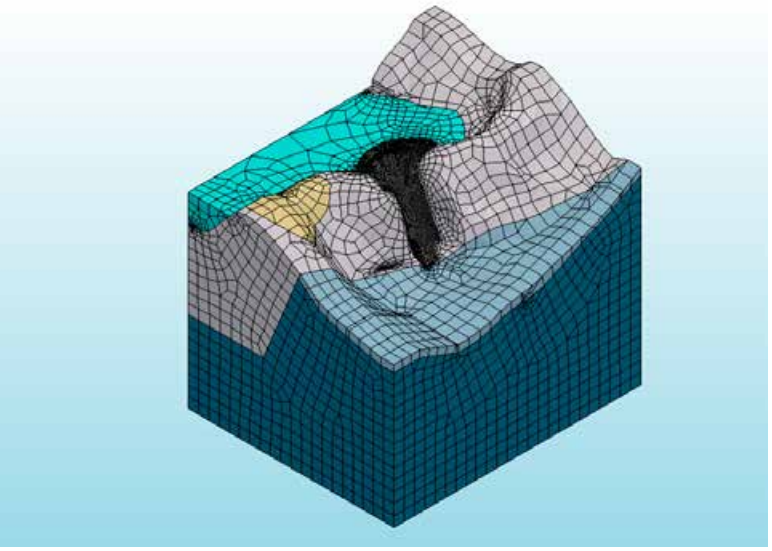
- geological-geomechanical inspections of the banks of reservoirs and derivation channels
- inspections of concrete, with additions made to cadastres of cracks and other damages
- diving inspections

The measurements evaluate deformation of the dam, groundwater filtration around the dam and the external load of the dam, and include:

- measurements of the vertical and horizontal displacements of the geodetic points observed
- measurements of the inclinations of dam structures
- measurements of the performance of individual cracks and expansion joints
- measurements of piezometric levels and uplift pressures
- measurements of specific electrical conductivities and water temperatures
- measurements of drainage flows
- measurements of water levels in the reservoir
- measurements of air temperatures
- measurements of the ground acceleration
- thermo-graphic measurements

For a better insight into the condition of the dam structures, measurement of the important parameters has been automated, and, over the years, the technical observation systems have also been updated.
The data obtained through technical observation of the dams are also used for 3D numerical analy-

ses, namely for the calibration of numerical models for calculating the static and dynamic safety of the dams. We have conducted such analysis for three dams over recent years (Vrhovo, Završnica and Moste).




WARNING / AVERT
H_2

Who We Are and What We Do

Laboratory for Stone, Aggregates and Recycled Materials

The laboratory operates across a broad spectrum of research and development, spanning the fields of circular construction, sustainable resource use, environmental acceptability, and the technical suitability of materials from secondary raw materials. At the same time, it maintains the tradition of investigating the conventional construction materials of stone and aggregates, as well as recycled materials. Both at the scientific level and within applied research, our work is directed towards the implementation of good practice, as derived from experience and in-depth engineering knowledge. We closely cooperate with research institutions and various branches of industry. The core of the laboratory brings together a multidisciplinary team of researchers and engineers in the fields of geology, construction, chemistry and the environment, including leading experts for the preparation of technical assessments and approvals, and authorized persons for product certification.

Head of laboratory: dr. Primož Oprčkal, univ. dipl. inž. geol.

Activities

- Investigation of natural, manufactured, and recycled aggregates
- Investigation of natural, agglomerated, and armour stones
- Investigation of potential use of recycled materials and industrial by-products for construction products, including the assessment of their environmental acceptability and technical suitability
- Investigation of materials in the area of cultural heritage
- Development of life cycle analysis models for recycling processes
- Mineralogical, petrographic, and microstructural analyses of aggregates and recycled materials
- Microtomographic analyses of materials
- Chemical analyses of construction products and materials
- Analyses of the presence of asbestos in construction materials, air filters, water, and environmental samples

Research & development

- Methods and technologies for the remediation of contaminated soils, materials and water
- Cascade recycling, including the extraction of critical raw materials
- Implementation of recycled waste into construction products and structures
- Research into the pathology and potentially harmful processes associated with the use of aggregates and secondary raw materials in cement matrices and construction products
- Research into air pollution as a result of particulate matter
- Development of circular models and business systems
- Modeling environmental impacts within the life cycle of recycled materials, techno-economic analyses
- Digital construction (BIM) and tracking flows from waste generation to incorporation
- Microtomography of materials and 3D image analysis
- Research into materials and the preservation of cultural and industrial heritage

Projects

- ReBuilt – Circular and digital renewal of central Europe construction and building sector (Interreg Central Europe, 2023–2026)
- LIFE HIDAQUA – Sustainable water management on high water demanding industries (LIFE, 2019–2025)
- LIFE IP RESTART – Boosting Waste Recycling into Valuable Products by Setting the Environment for a Circular Economy in Slovenia (LIFE, 2022–2030)
- CO2TREAT – Accelerated CO_2 Treatment of alkaline residues for low carbon binders (ERA MIN, 2022–2025)
- ZnOrgBat – Rechargeable Zinc-organic batteries (EIT RawMaterials, 2024–2025)
- WEEE-NET9 – Improving CRMs extraction capacities in RIS WEEE recycling (EIT RawMaterials, 2022–2024)

Horizontal activities

- Collaboration with the group for material investigations in cultural heritage, Sherezad
- Collaboration with the microtomography group
- Collaboration with the 3D printing group

Laboratory for Concrete

The laboratory is a state-of-the-art laboratory for research and development in concrete and concrete technology. The laboratory provides technical and professional support to producers and users facing problems or questions related to concretes, their preparation, installation and quality proofing.

Head of laboratory: dr. Aljoša Šajna, univ. dipl. inž. grad.

Activities

- Quality control of concrete, concrete products and other cementitious composites
- Quality control of the execution of concrete works
- Concrete testing and analysis
- Testing of concrete products
- Inspections, opinions, expert opinions
- Training

Research and development

- Introduction of new technologies, e.g. digital manufacturing or 3D printing, of cement composites
- Research on the rheological properties of fresh concrete
- Research on special concretes and other cementitious composites (self-compacting, micro-reinforced, high-grade, drainage concretes)
- Implementation of recycled secondary raw materials in concretes
- Research on advanced sustainable concretes and mortars for rapid, durable and sustainable construction, rehabilitation and protection of AB structures
- Non-destructive testing of cultural heritage concretes

Important research equipment

- Digital production or 3D printing station for cement composites (software, mixer, pump, arm)
- Viscometer for measuring the rheological properties of fresh concrete...
- Equipment for measuring the pore distribution of fresh concrete Air Void Analyser AVA 3000
- Confocal-metallographic microscope for determining the size distribution and pore characteristics in hardened concrete (according to SIST EN 480-11)
- Isothermal calorimeter for measuring the hydration heat of concretes
- CO_2 chamber for accelerated determination of the resistance of concrete to carbonation
- Equipment for measuring the air permeability of concrete (Torrent)

Projects

- CIRCUIT – Holistic approach to foster circular and resilient transport infrastructures and support the deployment of green and innovation public procurement and innovative engineering practices (HORIZON, 2023–2027)
- L2-50045 – Two-filament 3D Printing with Concrete and Earth (ARIS, 2023–2026)
- TRANSITION – Transforming waste into high-performance 3D printable cementitious composites (M-ERA.NET, 2023–2026)

Horizontal activities

- Managing the 3D printing group
- Participation in the group for investigations of materials in cultural heritage – Scheherazade

Laboratory for Metals, Corrosion and Anti-Corrosion Protection

In the laboratory we combine professional excellence with the latest advancements in development and research, utilizing cutting-edge equipment. We provide comprehensive technical and professional support in the areas of metals, corrosion, and anti-corrosion protection. We collaborate with industries, companies, and individuals who face challenges or have inquiries related to metals. Our laboratory brings together researchers and experts from diverse fields, including metallurgy, chemistry, mechanical engineering, physics, and civil engineering. Our team is actively involved in a range of domestic and international research projects, professional associations and working groups.

Head of laboratory: dr. Tadeja Kosec, univ. dipl. kem.

Activities

- Investigations into and testing of metal materials, products and systems
- Investigations into and testing of metallic and non-metallic corrosion protections
- Non-destructive investigations of defects and damages in metal elements, welds and other joints
- Assessments, opinions, expertise, inspections and controls
- Consulting and education

Research and development

- Development and fabrication of sensors for monitoring corrosion in various applications
- Monitoring corrosion and repassivation processes in different environments
- Stress corrosion cracking mechanisms and the hydrogen embrittlement mechanism
- Corrosion processes in water supply systems
- Corrosion and tribocorrosion of new materials
- Study of corrosion and protection of objects of cultural heritage
- Material degradation in deep geological nuclear waste repositories

Projects

- Understanding H-embrittlement mechanisms in additive manufactured stainless steels (CEA, 2024–2025)
- ACES – Improved assessment of NPP concrete structures toward ageing (H2020, 2020–2024)
- CastQC – A novel cast ultra high specific strength quasicrystal Al alloy (EIT RawMaterials, 2022–2024)
- EURAD II European joint programme on Radioactive waste management (HORIZON, 2024–2028)

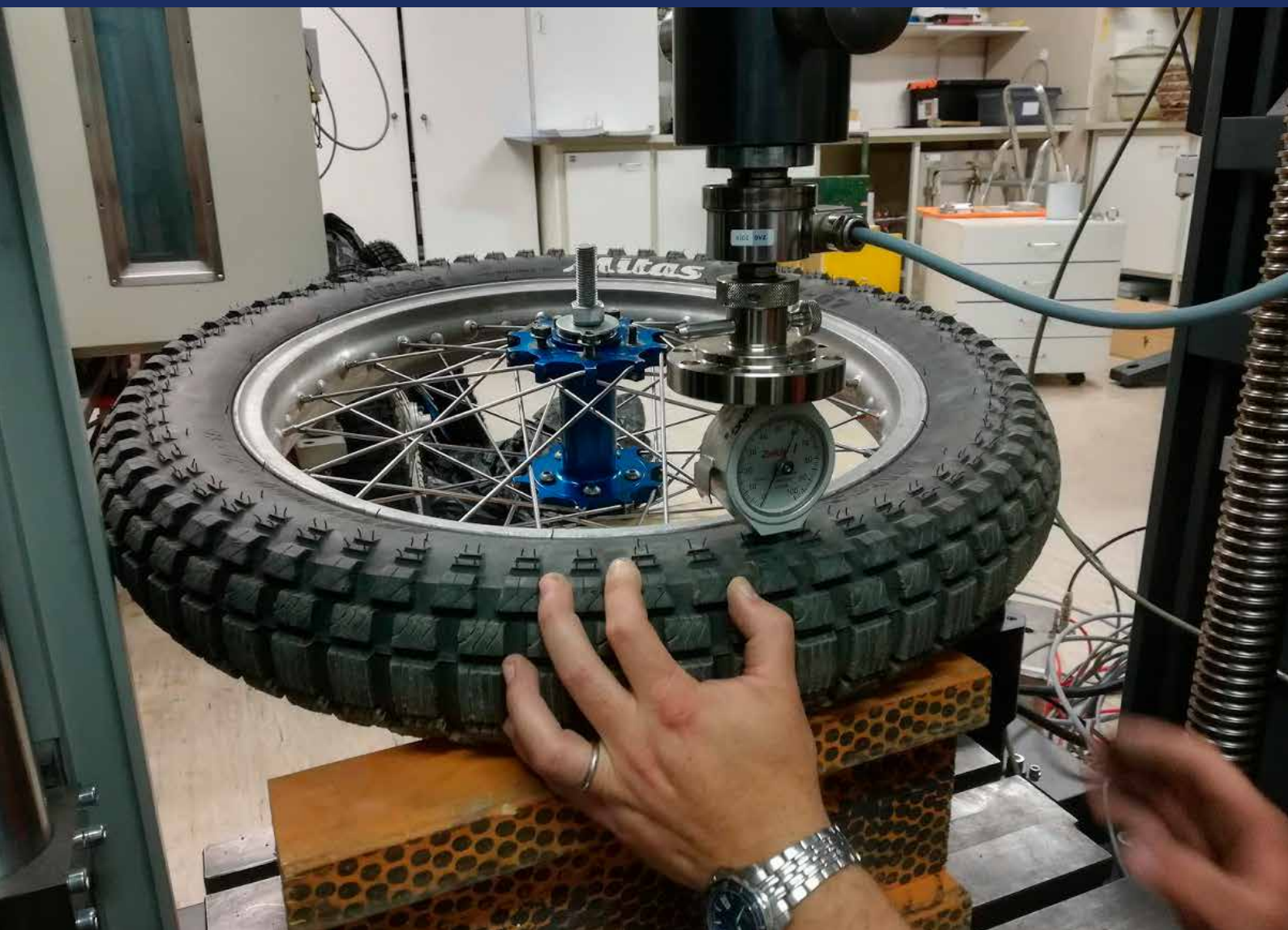
Horizontal activities

- Cooperation of the group for investigations of materials in cultural heritage - Sherezad
- Participation in the microtomography group
- Participation in the 3D print group

Laboratory for Polymer Materials

The laboratory is primarily focused on the applied use of cutting-edge knowledge in the field of materials and testing of materials. We regularly cooperate with industrial partners and we always strive to offer relevant services that are important for them to operate successfuly. The services that our partners can expect include support in the development of innovative products and in placing these products on the market, as well as assistance with various challenges they face in their operations or wherever they need an expert opinion or further support. In our work, we also rely on our extensive expertise on the legislation of construction products, at both the Slovenian and European level. The laboratory is also involved in the external quality control of materials used in the construction of roads, railways and other infrastructure objects in Slovenia, as well as in the certification of construction products.

Head of laboratory: Gregor Strmljan, univ. dipl. inž. kem. inž.



Activities

- Cooperation with industrial partners and support in their activities
- Testing the mechanical properties of polymers and other composite materials
- Quality control of polymeric building materials
- Preparation of European Technical Assessments (ETA) and Slovenian Technical Approvals (STS) for construction products
- Involvement in the certification of construction products

Research and development

We have state-of-the-art testing equipment to offer a wide range of services to our clients. We also draw on many years of experience in testing various materials and knowledge of building and other legislation. The services we provide include, but are not limited to:

- Development of new test methods tailored to specific customer needs
- Consulting and support in the development of new products
- Consulting and support in placing products on the market

Supporting horizontal activities

- We advise colleagues from other laboratories in the field of materials and materials testing
- We develop and perform advanced test methods

Section for Functional Materials

The section primarily deals with scientific research work focused on the development and analysis of advanced, renewable and functional materials that are mainly used in the construction industry. We introduce new, advanced investigations and technologies, participate in educational processes at faculties and advise industrial partners in the field of functional materials, cooperate with development-research and educational institutions in Slovenia and abroad, actively participate in important domestic and international conferences and symposia and regularly publish articles in international scientific journals.

Head of section: Gregor Strmljan, univ. dipl. inž. kem. inž.

Activities

- Research activities and the development of new functional materials
- Active participation in the scientific community
- Cooperation with industrial partners in the development of innovative, functional materials
- Execution of advanced analyses
- Support the research activities

Research and development

- Development of new materials for a healthy living environment: research and development of indicators/sensors for the qualitative and quantitative identification of relative humidity, volatile organic substances, carbon dioxide and pathogens in the air inside buildings
- Research on advanced renewable composite materials: modification of wood materials and composites to increase their fire resistance and durability
- Use of nanomaterials in construction: research into advanced photocatalytically active materials for the purification of water and air and to obtain energy-rich compounds
- Development of functional coating systems to provide durable and efficient building surfaces
- Development of innovative solutions for the strengthening and protection of materials used in cultural heritage objects, including hardeners, impregnations, and coatings
- Research into the impact of microplastics on the environment
- Studies investigating the possibility of using waste polymers in the construction industry and the development of technological procedures for recycling

Research projects

- J7-50231 – GROWTH, Growth potential and the properties of wood from selected tree species of different origin: possibilities of protection by modification and challenges in responding to climate change (ARIS, 2024–2027)
- J7-50226 – NextGenHS, Next-generation analytical tools for heritage science (ARIS, 2024–2027)
- CRP, Preparation of a proposed methodology for assessing the risk to human health associated with the release of volatile and semi-volatile organic compounds from construction and finishing materials and equipment into the air inside premises (VOC, 2023–2024)
- J2-4424 – An integrated approach towards the preservation of wall paintings of cultural heritage (ARIS, 2022–2025)
- 4-4546 – Protein adhesives for high-performance wooden structures used indoors ARIS, 2022–2025)
- J2-4441 – Dual-acting Nb2O5 and Nb2O5-TiO2 materials for the simultaneous reduction of CO_2 and oxidation of organic substances into compounds with added value (ARIS, 2022–2025)

Horizontal activities

- Participation in the Cultural Heritage Materials Investigation Group, Sherezad
- Participation in the microtomography group
- Participation in the 3D Printing Group

Laboratory for Cements, Mortars and Ceramics

The laboratory provides technical and professional support with respect to a wide range of materials, including mineral binders and additives, mortars, ceramics and certain secondary raw materials. The laboratory collaborates with all branches of industry, as well as representatives of other institutes and faculties active in this field. It brings together experts and researchers from various complementary fields (chemistry, civil engineering, geology, amongst others). Our staff are the leading experts of the Service for Technical Approvals, and authorised people for the certification of this type of products. We are actively involved in national and European projects and associations, such as RILEM, COST, SIST, KIC and NEB, amongst others. We present the results of our work at national and international conferences and in scientific publications and monographs.

Head of laboratory: dr. Vilma Ducman, univ. dipl. inž. kem. inž.

Activities

- Investigation of mineral binders, mineral additives, mortars, chemical admixtures for concrete, cementitious adhesives and grouts
- Investigations on brick products
- Testing of road de-icing salts
- Determination of water aggressivity for concrete
- Determination of the slip resistance of floor surfaces
- Petrographic-mineralogical investigation of building materials
- Microtomographic analyses of materials, especially those used in construction
- Assessments, opinions and training

Research and development

- Alkali-activated materials
- Low carbon cements and hydration processes
- Carbonization and sequestration
- Artificial aggregates based on various waste
- Earth-based products (unfired clay)
- Use of secondary raw materials in the building materials industry

Projects

- AshCycle – Integration of Underutilized Ashes into Material Cycles by Industry-Urban Symbiosis (HORIZON, 2022–2026)
- GEORIS – Innovative technologies for waste processing in ESEE Region (EIT RawMaterials GEORIS, 2022–2024)
- STILLMETAL – Sustainable slag process to obtain a valuable metal (EIT RawMaterials, 2022–2024)
- WIN – Waste Utilisation for Alkali Activated Materials (SI-AT WIN, 2023–2026)
- TRANSITION – Turning waste into a high-value cementitious composite for 3D printing (M-ERA.NET, 2023–2026)
- J1-50032 – Geological and litho-geochemical characterisation of Slovenian dolomites coupled by trial magnesium extraction (ARIS, 2023–2026)
- J7-50226 – Next Generation Analytical Tools for Heritage Science project (ARIS, 2024–2027)

Horizontal activities

- Leading the Cultural Heritage Materials Investigation Group, Sherezad
- Participation in the microtomography group
- Participation in the 3D Printing Group

Laboratory for Building Physics

Researchers and experts from the laboratory combine knowledge from the fields of heat, light, acoustics, humidity and air quality with respect to the physical-construction processes in the built environment, the efficient use of energy and renewable energy sources in buildings and influences on the health of users, analyses on the life cycle of buildings, the impact of construction products on the environment and evaluating the sustainability of buildings. Through our rich experience, and the continuous acquisition of new knowledge in the areas listed, we ensure professional excellence and successfully cooperate with industry, companies and individuals, offering them extensive professional and technical support in the construction process and helping them meet the legislative requirements of the construction industry.

Head of laboratory: doc. dr. Katja Malovrh Rebec

Activities

- Laboratory tests and investigations
- Field measurements and testing
- Numerical simulations
- Assessments, professional opinions, expertise
- Analyses of the life cycle of buildings
- Evaluating the sustainability of buildings
- Education

Research and development

We research and develop in the field of thermal and sound insulation materials, multifunctional building elements (especially the building envelope), comprehensive energy renovations and the efficient use of energy, functioning of buildings from the perspective of sustainability, and use of sustainability indicators to evaluate buildings both in Slovenia and abroad. We are engaged in research related to environmental noise, specifically on roads, with our research work directing user-oriented concepts for infrastructure and services in cities. Through our activities, we connect with other research institutes, work with associations and cooperate in research projects. The results of our research and development work are regularly published in both domestic and foreign journals and presented at conferences. In addition to assessing the responses of elements and materials, we measure direct responses of individuals to building conditions, especially with respect to light and warmth. In 2023 we organised an international doctoral summer school through IPERION HS, entitled “Environmental impact on built heritage and its digitalization”.

Projects

- BUILDCHAIN – BUILDing knowledge book in the blockCHAIN distributed ledger (HORIZON, 2023–2025)
- CirCon4Climate – Circular Construction Practices for Climate Action (EUKI, 2022–2025)
- MEZeroE – Measuring Envelope systems for Zero Energy buildings (H2020, 2021–2026)
- E-RIHS – European Research Infrastructure for Heritage Science Implementation Phase
- N2-0258 – Study of thermal properties and lifetime impact reduction of alternative hybrid eco-nanomaterials in a low pressure environment (ARIS, 2023–2024)
- Development of technical guidelines for quadruple glazing
- V4-2270 – Faster transition to a climate-neutral society by exploiting the potential of wood in the context of green public procurement (ARIS, 2022–2023)

Fire Laboratory and Fire Engineering

The laboratory has been testing fire properties of products and structures in construction and shipbuilding for 50 years. We carry out both standard and non-standard tests as well as research and development in the field of fire, including reaction to fire and fire resistance, smoke and heat extraction and facade fire. We also perform analyses of real fire sites and studies of fire safety in buildings. Our team is involved with procedures relating to the placement of construction products on the market. We are also an active member of the European association of fire laboratories (EGOLF) and other international bodies, including EOTA and CEN. Research primarily concerns the fields of fire - with an emphasis on the behaviour of wood and wood-based composites in fire - and sustainable construction, focussing on the development of both sustainable products and system solutions for the implementation of sustainable construction in practice.

Head of laboratory: Friderik Knez, univ. dipl. fiz.

Activities

- Testing fire properties of various products used in construction and shipbuilding
- Implementation of modified, non-standard target development tests for industry in both, Slovenia and wider Europe
- Preparation of expert opinions on the fire properties of various products, fire safety problems, the causes, origin and spread of fire, and inspection and assessment of structures damaged by fire
- Preparation of fire safety studies according to the requirements of Slovenian legislation
- Research supporting a systemic approach to sustainable construction in Slovenia and the EU
- Development of guidelines and pilot systems to mitigate radon in buildings with elevated indoor concentrations

Research and development

- Research in the field of toxicity and ecotoxicity of fire affluents
- Research concerning sustainable construction in connection to fire
- Research on the behaviour of wood and wood-based composites in a fire, specifically concerning the initial phase of a fire (i.e. reaction to fire)
- Research into the fire properties of products made from secondary materials
- Research with respect to fire risk, building materials, products and constructions made of wood and other natural materials
- Development of guidelines and research with respect to protecting buildings against the harmful effects of radon at both, a national and international level

Projects

- FRISSBE – Fire-safe Sustainable Built Environment (H2020, 2021–2026)
- MEZeroE – Measuring Envelope systems for Zero Energy buildings (H2020, 2021–2026)
- GREEN LOOP – Sustainable manufacture systems towards novel bio-based materials (HORIZON, 2022–2025)
- STAR-track – Support and networks To Accelerate the construction and Renovation innovation track to market (Obzorje 2020, 2024–2027)
- LIFE IP CARE4CLIMATE – Boosting greenhouse gas emissions reduction by 2020 with a view to 2030 (LIFE IP in MOP, 2019–2026)
- POCYTIF – A POsitive Energy CITY Transformation Framework (H2020, 2019–2024)
- RENOINVEST – Roundtables enhancing smart investments in sustainable renovation of buildings (LIFE, 2023–2026)
- L2-50046 – Assessing and improving the fire performance of building envelope systems – with a focus on etics systems (ARIS, 2023–2026)
- J2-50063 – Sustainable long-term use of timber structures - fire and post-fire deterministic and probabilistic solutions (ARIS, 2023–2026)

Fire Research and Innovation Unit

The unit deals with various types of fire research and aspects of safety. The unit was established as a result of a successful project application to the ERA Chair Horizon 2020 call, which formed part of the 'Spreading Excellence and Widening Participation' work programme. The unit aims to create and support an intense R&D centre concerned with fire safety and a sustainable built environment, focussing on Southern and Central Europe. We also aim to foster networking in the field of fire research in Slovenia and strengthen cooperation with the industry.

Head of unit: ddr. Aleš Jug, univ. dipl. oec., var. inž.

Activities

- Investigating the causes of fires: Analysing how and why fires start, including research into different combustible materials, ignition sources, the conditions that contribute to fire, and the circumstances in which fires most commonly occur.
- Fire modeling and simulation: We develop and use computer models and simulations to predict fire behaviour in different environments. This includes modeling flame spread, smoke and heat.
- Fire dynamics research: We study the physical and chemical processes during a fire, such as combustion, flame propagation and smoke formation.
- Testing of materials and building elements: We test different materials and building elements to assess their fire resistance, including laboratory tests and experiments under controlled conditions.
- Fire safety development: We develop guidelines, standards and regulations to improve fire safety in buildings, infrastructure objects and other environments. This includes research into fire protection measures, such as fire alarms, sprinkler systems and fire barriers.
- Education and training: We organise seminars and trainings for fire safety professionals and raise public awareness regarding fire safety.

Research

- Fire research in the study of ETICS facade systems
- Fire research on the combustion dynamics of Li-ion batteries
- Numerical methods in fire (multi-scale modeling, modeling of the combustion process and mechanical analysis)
- Hybrid and advanced experimental methods in fire (numerical/experimental integration, toxicity analysis methods, the progression of fire through facades)
- Emission analysis, toxicity and ecotoxicity in fire (determining the composition of combustion flue gases, biomass burning)
- Fire research related to solar power plants (different roof types, combustible and non-combustible insulation, different solar panel layouts)
- Fire research on structures (wood, geopolymers and composite structural elements in fire)
- Fire research into materials (bio-based composites, advanced thermal insulation, geopolymers)

Projects

- FRISSBE – Fire-safe Sustainable Built Environment (H2020, 2021–2026)
- MEZeroE – Measuring Envelope systems for Zero Energy buildings (H2020, 2021–2026)
- L2-50046 – Assessing and improving the fire performance of building envelope systems – with a focus on etics systems (ARIS, 2023–2026)
- Ti-Rex – Framework for smart condition reassessment of Reclaimed Timber to extend the service life of long-lived wood products using non-destructive testing and automated data postprocessing (ForestValue2, 2024–2027)

Section for Building Structures and Earthquake Engineering

The section covers a broad subject area related to ensuring the mechanical resilience of buildings and their load-bearing structures. With the wide knowledge gained through decades of experience from several generations of structural engineers, our section provides support to industry and decision-makers both at home and abroad. The section is engaged in research on structural behaviour and the development of structural elements, systems and buildings. It develops methodologies and guidelines to reduce the seismic vulnerability of the built environment. Based on in-situ and laboratory investigations, and computational analyses of existing structures, our team offers expert guidance in the renovation or rehabilitation of buildings in the context of design or emergency response. It also participates in the preparation of technical approvals and prepares other demanding expert reports related to the safety and reliability of load-bearing structures.

Head of section: dr. Meta Kržan, univ. dipl. inž. grad.

Activities

- Structural condition surveys, computational analyses and seismic performance assessments of existing buildings (e.g. for guidance in renovation, emergency response measures)
- Laboratory and in-situ experimental investigations of structural elements, assemblies and structures
- Seismic risk analyses of building stock
- Structural load tests in various building structures
- Geodetic and other technical monitoring
- Participation in the preparation of standards, technical assessments and compliance verifications
- Expert services and opinions

Research and development

- Behaviour of building and engineering structures under seismic loading
- Effectiveness of systems for the seismic strengthening of existing building structures
- Seismic performance of new structural elements and systems
- Experimental testing and analytical methods to determine the behaviour of structural elements or systems
- Basis for the development of strategies to reduce the seismic risk related to specific building stock

Projects

- CRP ARIS V2-2257 – Strategic Basis for the Reduction of Seismic Risk of Judicial Buildings in Slovenia (ARIS and Ministry of Justice, 2022–2025)
- GreenRenoV8 – Cost-effective building stock decarbonization and seismic resilience: Incorporating EPBD implementation in renovation plans and passports (LIFE, 2024–2027)
- Expert bases for preparing the Action Program for Enhancing Earthquake Safety based on the Resolution on Earthquake Safety Enhancement until 2050 (Ministry of Natural Resources and Spatial Planning, 2024–2025)
- POTROG4 – Upgrade of the seismic risk assessment and response system to support the earthquake protection and rescue service in the Republic of Slovenia (Ministry of Defence, 2019–2020)

Section for Bridges and Engineering Structures

Our vision is to integrate research and high-level professional work in the field of bridge management in order to meet the applied needs of the industry. Most of us are experts in the field of structural engineering. We perform periodic and special inspections of complex structures, safety assessments of existing structures, comprehensive structural monitoring, load testing of bridges, vibration measurements, and more. We also participate in the preparation of technical guidelines and technical approvals. Through our long-standing, recognized, and successful research work, we collaborate with domestic and international researchers, provide industry support in development, and are active in national and international organizations and associations.

Head of section: dr. Andrej Anžlin, univ. dipl. inž. grad.

Activities

- Different types of bridge inspections
- Laboratory and field tests of bridges
- Safety assessment of existing bridges
- Load testing of infrastructure structures
- Vibration measurements of structures
- Expert services and opinions
- Participation in the preparation of standards, action plans, technical assessments and compliance verification

Research and development

- Safety and sustainability of bridges
- Monitoring of structures
- Weigh-in-motion
- Digital bridge inspection
- Reuse of old/existing load/bearing elements
- Flood and seismic vulnerability of bridges
- Modeling the static and dynamic behaviour of bridges

Major items and equipment

- Equipment for measuring structural responses and monitoring long-term structural health monitoring (measurement of accelerations, rotations, displacements and strains)
- Equipment for non-destructive in-situ investigations of structures
- Equipment for measuring vibrations according to DIN 4150-3 (velocity sensors and remote-access measurement system)
- Unmanned aerial vehicles (drones)
- Software for the structural analysis and data processing of measurements

Projects

- BIM4CE – Bridge monitoring using real-time data and digital twins for Central Europe (Interreg Central Europe, 2022–2025)
- CIRCUIT – Holistic approach to foster CIRCUlar and resilient transport InfrasTructures and support the deployment of Green and Innovation Public Procurement and innovative engineering practices s (HORIZON, 2023–2027)
- CrossCade – Cross-border cascading risk management for critical infrastructure in Sava river basin (UCPM, 2022–2024)
- J7-5009 – Improving B-WIM performance with big data and Artificial Intelligence BrAId (ARIS, 2023–2026)
- Development projects with respect to digitalizing the process of monitoring the condition of bridges managed (DARS in DRSI)
- Monitoring the condition of bridges on roads managed by DARS – principal and special inspection
- Development and Research Activities on the SiWIM Bridge Weigh-in-Motion system

Section for Metal and Polymer Structures

The section unites researchers and experts with many years of experience in various specialties of civil and mechanical engineering. We co-operate with industry representatives and companies facing problems or dilemmas in any of our areas of expertise. Furthermore, we develop and introduce new testing methods in the field of non-standard testing. A Control Body for Cableway Installations (Type C in accordance with the standard SIST EN ISO/IEC 17020:2004) also operates within the scope of the section.

Head of section: dr. Iztok Klemenc, univ. dipl. inž. grad.
Head of the Control Body for Cableway Installations: Milan Grkman, univ. dipl. inž. str.

Activities

- Technical and professional support for the introduction of new technologies and the implementation of new regulations in the field of metal and polymer structures, as well as for ground anchors, rock bolts and soil nails
- Field measurements, inspections and condition assessment of building structures and structural elements in-situ (steel bridges, poles, transmission line pylons, etc.)
- Involvement in tasks for ZAG's Technical Assessment and Approval Service in the preparation of European Assessment Documents (EADs), European Technical Assessments (ETAs) and Slovenian Technical Approvals (STSs)
- Coordination, consultancy and guidance; processing and analysing the results of various laboratory tests, investigations and measurements of structural assemblies, elements and construction products
- Preparation of expert assessments, opinions and expertise, based on inspections, surveys and/or prior documentation
- External quality control of steel structures, ground anchors, rock bolts and soil nails within infrastructure (motorways, roads, railways, hydroelectric power plants, etc.)
- Performing tasks for ZAG's Certification Service, in its capacity as an authorised body for construction products, within the scope of the section's activities
- Conducting magnetic inductive testing of steel wire ropes on cableway and mining installations
- Carrying out technical inspections of cableway installations, inspections and tests of their subsystems within the framework of the Control Body for Cableway Installations
- Education and training

Development

- Developing and introducing new methods and technologies for testing the behaviour of metallic and polymeric structures under static and dynamic loads
- Load testing and condition assessment of prestressed ground anchors, rock bolts and soil nails
- Condition assessment, observation and rehabilitation of ground anchors and existing steel assemblies, structures and structural elements

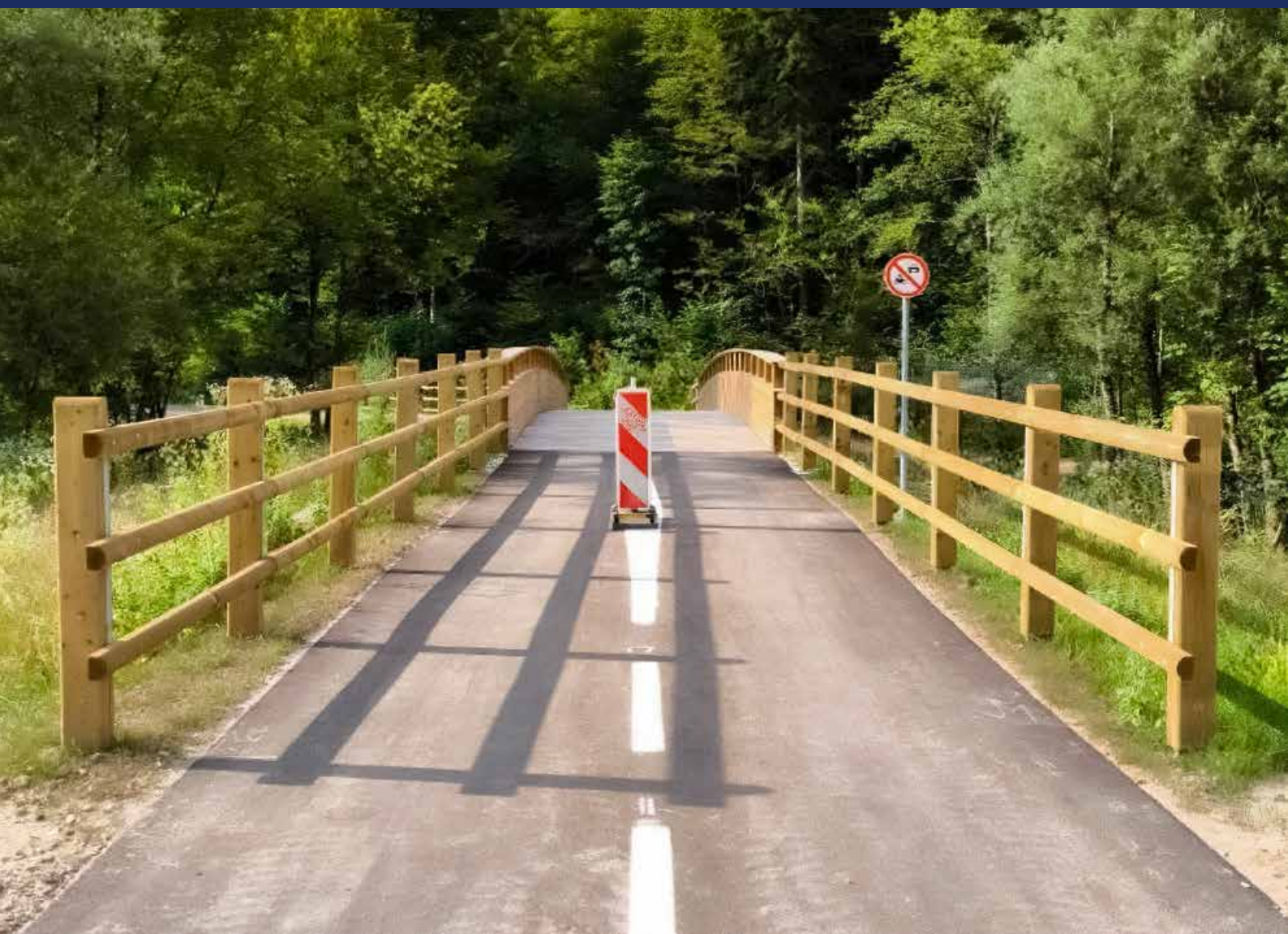
Equipment

- Electro-magnetic inductive wire rope testers for inspecting steel cables
- Wire rope tensiometer for measuring tensile forces in loaded steel cables
- Pull-out test kit for soil nails and rock bolts (self-drilling grouted anchors, rebar bolts/SN anchors and hydraulic expansion friction anchors)

Section for Timber Structures

The section intertwines comprehensive professional and research work in the field of timber structures, paying attention to the base material, wood, and various wood-based products, as well as to other important materials/ products of sustainable construction. We successfully cooperate with domestic and foreign industry partners in the field of product testing, and this is now being further upgraded with joint development and research activities. We actively participate in national and international projects, sit on standardization committees, carry out various interdisciplinary project orders in the fields of research and education, and successfully cooperate with recognized universities both at home and abroad. The department's experts cover complementary areas of timber construction, and through joint development/research work and publication of our work we actively contribute to the development of the profession and science at a domestic and international level.

Head of section: dr. Tomaž Pazlar, univ. dipl. inž. grad.



Activities

- Technical and professional support in the introduction of new materials and technologies and enforcement of regulations in the field of wood-based products and timber structures
- In-situ inspection and assessment of timber structures
- Various laboratory tests, tests and measurements of various construction products based on timber and structural assemblies
- Assessments, expert opinions, expertise, inspections and controls, and quality control
- Involvement in the preparation of technical assessments and certification
- Education

Research and development

- Strength grading of timber
- (Non-destructive) methods for the assessment of timber structures
- Development of innovative glued and mechanical joints in timber structures
- Innovative structures made of wood-based materials
- Use of recycled/re-used wood-based materials as a raw material for new products
- Improving the mechanical, physical and durability properties of wood and wood-based materials

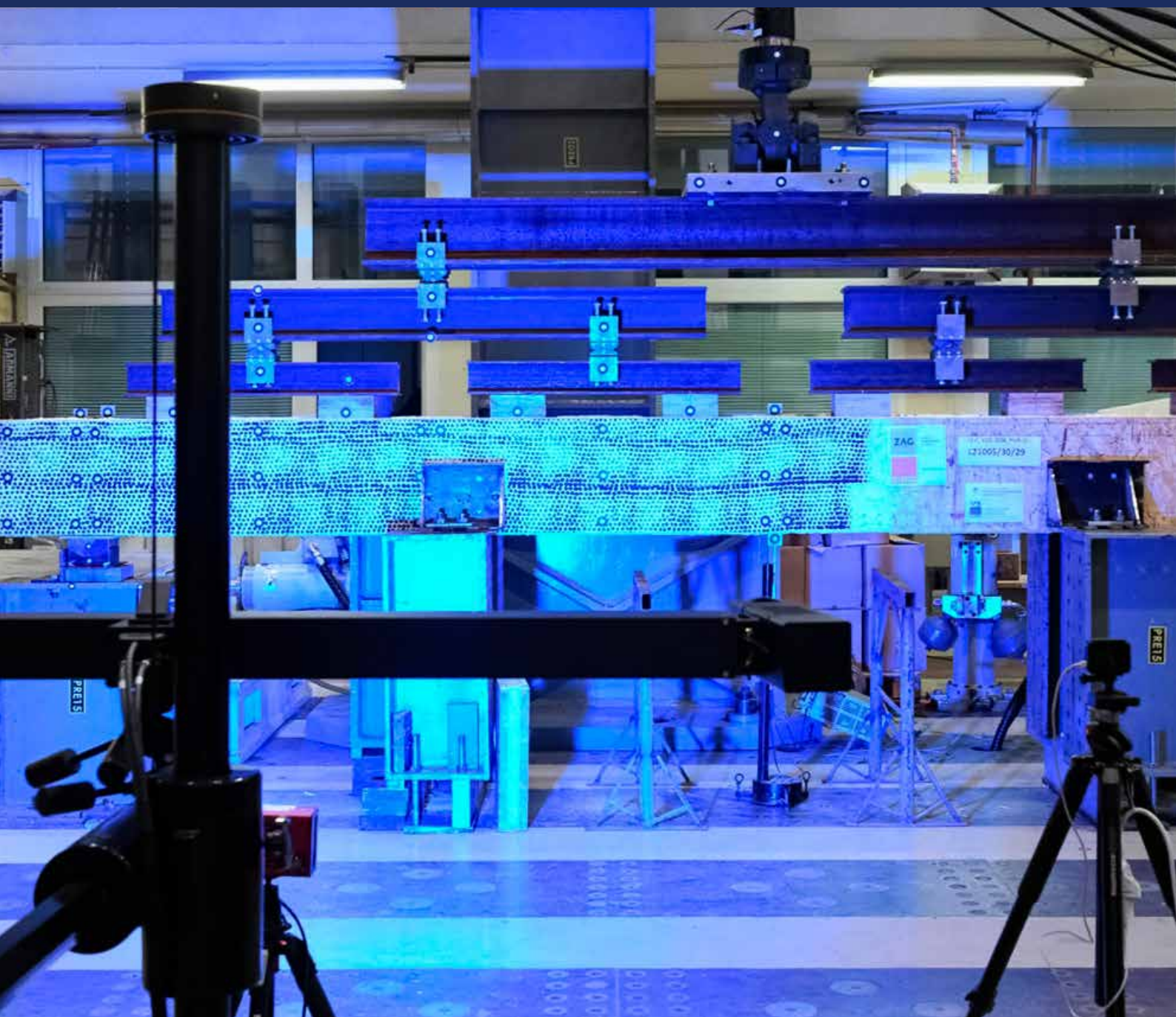
Projects

- V2-2350 – Ensuring the quality of sustainable timber construction (ARIS, MGTŠ, 2023–2024)
- J4-4546 – Protein adhesives for high-performance interior wooden structures (ARIS, 2022–2025)
- N2-0280 – DIAMONDS - DIAgnostics and Mechanical tests Of aged adhesive layers used in joiNts of wooDen structureS (DIAMONDS) (ARIS, 2023–2026)
- J7-50231 – GROWTH Growth potential and wood properties of selected tree species of various provenances: modification options, prospects and challenges in response to climate change (ARIS, 2024–2027)
- InnoCrossLam – Innovative Solutions for Cross Laminated Timber Structures (ForestValue, 2019–2022)
- Participation in the program group “Forest-wood value chain and climate change: transition to circular bioeconomy”

Laboratory for Structures

The laboratory, with its modern testing and measuring equipment, enables the most demanding mechanical tests to be set up and carried out on structural and other elements under static or dynamic loading. The professional and high-quality execution of tests is guaranteed by an interdisciplinary team with competencies in various fields. The laboratory's activities also include field inspections and tests using advanced non-destructive methods.

Head of laboratory: Uroš Ristić, mag. inž. grad.



Activities

- Carrying out various static and dynamic tests on structural and non-structural elements, with a maximum static load of up to 5000kN, a maximum dynamic load of up to 1000kN and frequencies up to 100Hz
- Field inspections, including the geodetic measurement of displacements and deformations and the sampling of installed materials
- Non-destructive testing of structural and other elements

Research and development

- Development of measurement methods for static and dynamic testing
- Introduction of non-destructive methods for detection structural health
- Development of optical methods for contactless measurement of displacement

Key equipment

- 14 x 26 m testing floor with a load-carrying capacity of 1000 kN/m^2 together with a 10 x 10 m strong floor, a 6 x 7 m reaction wall and a modular system of structural steel elements
- servo-hydraulic system allowing simultaneous loading for up to 8 hydraulic cylinders with capacities between 16 and 1000 kN
- single-component shaking-table with a 2.0 x 3.2 m platform (maximum payload: 5000 kg, maximum acceleration: 5 g)
- ZWICK universal testing machine with a capacity of 2500 kN
- axial-torsional dynamic test frame for combined axial/torsional loads (up to 25 kN/ 200 NM), equipped with an environmental test chamber
- several optical measurement systems for contactless measurement of displacements
- wide range of equipment for non-destructive testing: ultrasonic tomograph, GPR, Ferroscan, ultrasound, impact echo, etc.
- Zeiss precise levels, theodolites, optical plumbs, and total measurement stations

Section for Geotechnics

Using up-to-date equipment, and with the help of experienced professionals, we provide technical and professional support in earthworks, geotechnical surveys and monitoring. Our experts carry out national and international research projects and actively participate in professional associations and technical committees at a national and international level. We are responsible for the comprehensive quality control of materials and earthworks, conduct geological-geotechnical observations and plan the geological-geomechanical design of road and rail infrastructure, energy facilities and other complex geotechnical structures.

Head of section: dr. Stanislav Lenart, univ. dipl. inž. grad.

Expert activities

- Geomechanical ground investigations for buildings and civil engineering structures, including tunnels
- Geomechanical laboratory tests
- Geomechanical field investigations
- External quality control of earthworks
- Technical monitoring of structures such as dams, tunnels, retaining structures and embankments
- Geological-geomechanical design

Research work

- Research into the dynamic behaviour of soils in earthquakes or due to traffic
- Geomechanical investigations of unsaturated soil problems
- Geological and geomechanical investigation of rocks
- The use of geosynthetics in earthworks
- The use of secondary and waste materials in earthworks
- The resilience of infrastructure under different climatic conditions

Projects

- GEOLAB – Enhancing Europe's Critical Infrastructure (H2020, 2021–2025)
- CIRCUIT – Holistic approach to foster circular and resilient transport infrastructures and support the deployment of green and innovation public procurement and innovative engineering practices (HORIZON, 2023–2027)
- LIAISON – Lowering the environmental Impact of transport over the whole life cycle of future transport infrastructure (HORIZON, 2023–2026)
- Academics4Rail – Building a community of railway scientific researchers and academia for ERJU and enabling a network of PhDs (H2020, 2023–2025)
- SAFETY4TMF – Prevention and disaster management activities for Tailings Management Facilities (INTERREG DANUBE, 2024–2026)
- BRIDGITISE – Industrial Doctoral Network on Bridge Digitalised Integrity Management (HORIZON MSCA Doctoral Networks, 2024–2028)
- UPGRADE – Upgrading geomaterials: from waste to resource (HORIZON MSCA Staff Exchanges, 2025–2029)

Section for Road Maintenance and Management

The section provides technical and professional support in the maintenance and management of roads and conducts the characterisation of road surfaces. We apply and integrate non-contact measurement methods in transport infrastructure and its surroundings. We determine and evaluate the initial condition and geometry and monitor changes in the surface and condition of roads as well as changes in the natural environment. We collaborate with various experts in international and national research and development projects and actively participate in specialist conferences and meetings, both at a national and international level.

Head of section: mag. Darko Kokot, univ. dipl. inž. grad.

Activities

- Measurement of the characteristics of road surfaces, including unevenness, skid resistance, macrotexture and surface distress
- Management of transport infrastructure, the impact of road infrastructure on the environment, the energy consumption of transport, and greenhouse gas emissions
- Laser scanning to recognise infrastructure elements and built and natural spatial objects, as well as changes in their position and shape
- Expertise and consulting for road network operators and other investors
- Integration of the results from field measurements into management systems to optimise the allocation of financial resources for road maintenance
- Integration of new knowledge and research equipment into our daily work
- International networking with researchers and experts from various fields of work

Research and development

- Road infrastructure management
- Comparison of methods and equipment for monitoring various road surface characteristics
- Skidding properties to improve road safety
- Environmental impact of road construction and maintenance
- Non-contact laser measurement methods for recording and monitoring the condition of infrastructure, structures and the environment, and the protection of road infrastructure
- The digitalisation and management of infrastructure data

Projects

- AUGMENTED CCAM – Augmenting and Evaluating the Physical and Digital Infrastructure for CCAM Deployment (HORIZON, 2022–2025)
- INFRACOMS – Innovative & Future-proof Road Asset Condition Monitoring Systems (CEDR, 2022–2024)
- CoDEC – Connected Data for Effective Collaboration (CEDR, 2019–2021)
- Assets4Rail (H2020, 2018–2021)
- RAGTIME – Risk based approaches for Asset inteGrity multimodal Transport Infrastructure ManagEment (H2020, 2016–2019)
- ROSANNE – ROlling resistance, Skid resistance, ANd Noise Emission measurement standards for road surfaces (FP7, 2013–2016)

Laboratory for Asphalts and Bitumen-Based Products

In the laboratory we bring together experts with extensive experience in construction and chemistry. In addition to our research work, which we conduct in close collaboration with industry partners, we perform field and laboratory tests for investors and asphalt contractors. We also develop and introduce new methods for the non-standardized testing of bitumen and asphalt. We carry out more than 80 standardized tests in the areas of bitumen, asphalt, and waterproofing, 36 of which are accredited.

Head of laboratory: dr. Lidija Ržek, univ. dipl. inž. grad.

Activities

- Field measurements, inspections, and evaluations of asphalt and waterproofing works
- Preparation of expert opinions
- Quality control of completed works, both domestically and abroad
- Advanced testing of bitumen, asphalt, and bituminous waterproofing
- Preparation of Slovenian technical regulations in the field of asphalt
- Introduction of asphalt production at reduced temperatures
- Technical and expert support in exploring the use of asphalt granulates

Research and development

- Impact of aging on conventional road construction and polymer-modified bitumen
- Influence of the type and properties of asphalt on its resistance to fatigue and low temperature cracking
- Modeling the laboratory compaction of asphalt samples
- Impact of asphalt compaction on its durability
- Use of secondary raw materials in asphalt
- Correlations between bitumen properties and the behaviour of asphalt

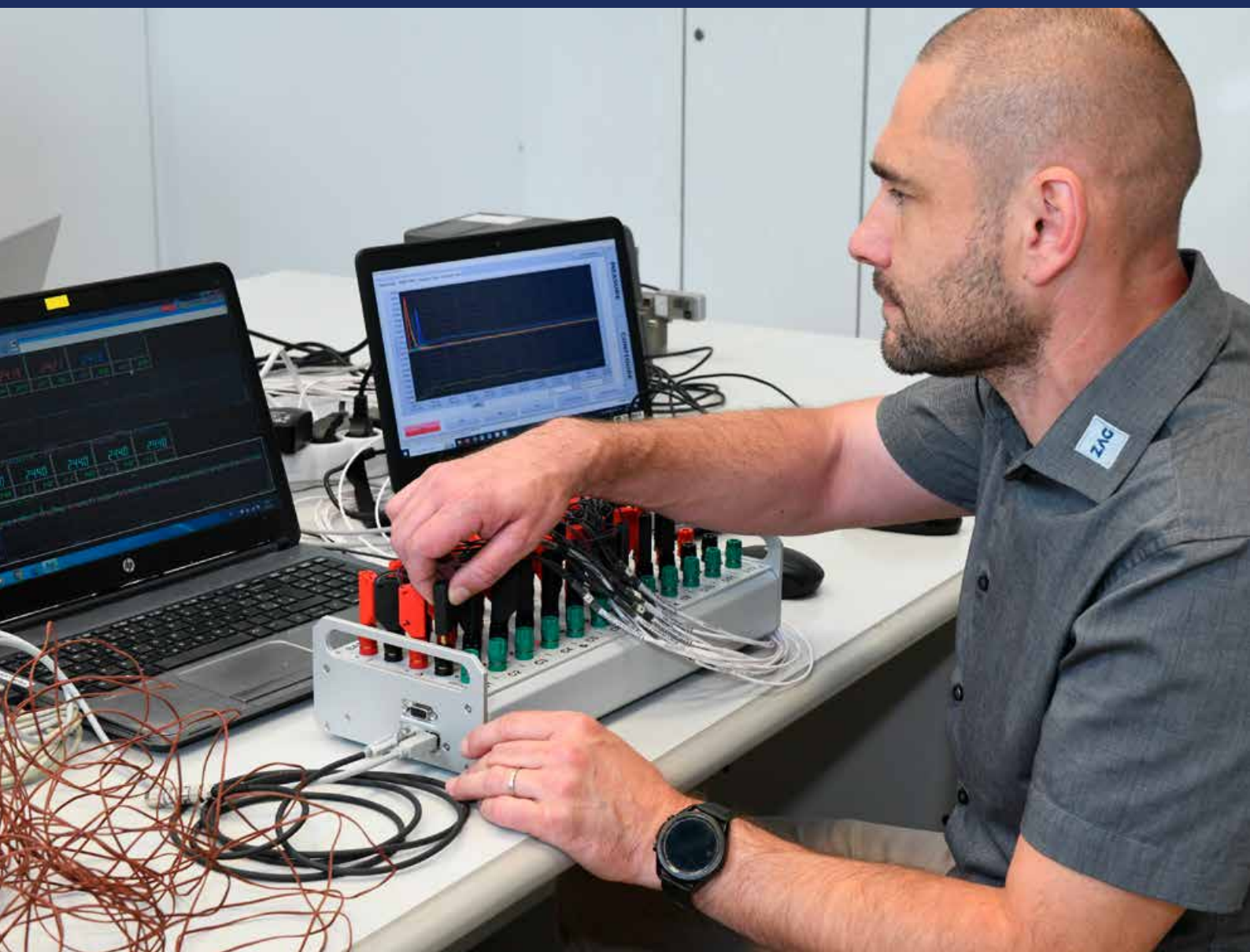
Projects

- Comprehensive quality control of asphalt and bituminous products for DARS
- Representing Slovenia in CEN TC 227 WP 1 (testing and verifying the conformity of asphalt mixtures)
- Participation in several RILEM projects (International Union of Laboratories and Experts in Construction Materials, Systems and Structures)

Laboratory for Metrology

The team performs calibrations and the verification of measurement and testing equipment in the laboratory, as well as on-site at clients' locations. The laboratory is accredited by the Slovenian accreditation according to the standard SIST EN ISO/IEC 17025 for the calibration of measuring instruments in the fields of force, torque, pressure, hardness, testing machines, impact strength meters, weighing scales, and temperature, amongst others. As the leading Slovenian calibration laboratory in the field of force and hardness, we assure the traceability of testing instruments for a wide range of users, from scientific research institutions to industry, both in Slovenia and abroad. Through cooperation with foreign national metrology institutes and universities, as well as membership in international metrology organizations, we contribute to the development of metrology at an international level.

Head of laboratory: dr. Miha Hiti, univ. dipl. inž. el.



Activities

- Maintenance of reference standards for force and hardness
- Calibration of measuring and testing equipment (mechanical quantities, length, temperature)
- Organizing and carrying out interlaboratory comparisons
- Inspections of measuring and testing devices and metrological maintenance
- Training in the field of metrology
- Participation in international metrological associations and co-preparation of guides and standards

Research and development

- Development of reference standards
- Research in the field of force and hardness calibration
- Research and development related to measurement instrumentation
- Analyzing and improving the uncertainty of calibration procedures

Projects

- TracInd BVK-H – Traceability for Indentation Measurements in Brinell-Vickers-Knoop Hardness (EMPIR, 2023–2026)
- ComTraForce – Comprehensive traceability for force metrology services (EMPIR, 2019–2023)

Certification Service

As a certification body (CB ZAG), ZAG's Certification Service focuses on continuous improvement of the quality of its services. For this purpose, a quality management system has been established according to the requirements of the standard EN ISO/IEC 17065. The effectiveness of this system is demonstrated by the internationally-recognised accreditation document, CP-002, issued by the organisation Slovenian Accreditation. CB ZAG is registered with the EU Commission as a certification body (identification number NB 1404) in accordance with the EU Construction Products Regulation (No. 305/2011), and has further been appointed as a certification body for all technical specifications outlined in Article 5 of the Slovenian Construction Products Act (ZGPro-1). The core of the Service is an interdisciplinary team of six employees, who cooperate with more than 30 experts from other departments in the institute as well as with various laboratories, both at home and abroad.

Head of service: mag. Egon Milost, univ. dipl. inž. grad.

Activities

- Certification of products and production controls related to the mandatory and voluntary certification of construction products
- Certification of other products, both regulated and voluntary
- Certification of initial test results for construction products and others
- Certification of the properties of construction products and other products
- Voluntary certification of various processes and services
- Voluntary certification of completed works

Development of new schemes

- Contributing to the establishment and upgrade of legislation, standardisation and conformity assessment procedures
- Considering the needs, wishes and problems of manufacturers, retailers and consumers of construction products, as well as those of designers and building contractors, and creating customised ZAG certification schemes

Key milestones

- 1996 – ZAG's Certification Service is established
- 1998 – First certificates of conformity are issued
- 2003 – CB ZAG becomes accredited according to the standard EN 45011 (CP-002)
- 2004 – ZAG is given the status of an EU notified body (No. 1404) according to the Construction Products Directive (89/106/EEC) and assumes the role of Slovenia's representative in the Advisory Group of Notified Bodies (AG GNB)
- 2006 – CB ZAG takes over leadership of the National Mirror Group for Conformity Assessment Bodies
- 2013 – ZAG fulfils the scope of activities to be an EU notified body in accordance with the EU Construction Products Regulation No. 305/2011
- 2015 – Upgrade of accreditation to the standard EN ISO/IEC 17065
- 2016 – Fulfils accreditation criteria for the purpose of notification according to the EU Construction Products Regulation No. 305/2011
- 2019–2022 – The head of ZAG's certification body is President of the European Group of Notified Bodies for Construction Products (GNB CPR)

The Service for Technical Assessments and Approvals

The service performs activities related to the award of Slovenian Technical Approvals, European Technical Assessments and Environmental Declarations for construction Products.
In 2003, ZAG was designated as an authorised body for Technical Approvals, and as such acquired the right to issue Slovenian Technical Approvals (STS) and European Technical Approvals (ETA).
In 2012, ZAG was designated as an Authority for Technical Assessment according to Regulation No. 305/2011/EU, thereby acquiring the right to prepare and issue European Technical Assessments (ETA).
Since 2013, the service has also prepared Environmental Product Declarations (EPD). Ownership of an EPD represents a good insight into the environmental parameters associated with the sustainability of construction products. In many European countries, this data is already mandatory or otherwise regulated.

Head of service: mag. Franc Capuder, univ. dipl. inž. grad.

Activities

SLOVENIAN TECHNICAL APPROVALS (STS)

An STS is granted at the request of a manufacturer who places a construction product on the market in the Republic of Slovenia which is not covered by the harmonised technical specification under the Slovenian Construction Products Act (ZGPro-1).

EUROPEAN TECHNICAL ASSESSMENTS (ETA)

An ETA is issued at the request of a manufacturer who places a construction product on the market in EU countries, when no harmonized standard exists for the product in question. The basis for the issue of an ETA is a European Assessment Document (EAD), which is prepared by the Technical Assessment Body (TAB) and approved by the European Organisation for Technical Assessment (EOTA) and the European Commission.

ENVIRONMENTAL PRODUCT DECLARATIONS (EPD)

An EPD provides a description of the product and the associated emissions over its entire life cycle. The EPD is based on the results of a life cycle assessment (LCA) and, although complex, represents a necessary and reliable basis for sustainable construction.

Memberships

- EOTA – European Organisation for Technical Assessment
- ECO PLATFORM – an association of European organisations that issue Environmental Product Declarations

Library

Our special library works in the field of science and has more than seventy years of tradition within our institution. It provides a public library service, intended for users of the parent institution as well as external visitors. It is registered in the library system of Slovenia, under the siglum/ISIL SI-50214.

Our mission is to carry out library, information and documentation activities, and management of the bibliography of our colleagues, wherewith we are actively involved in the scientific research and innovation activities of ZAG. With a rich collection and modern services, we strive to support the scientific research and professional work of our researchers, experts, and students in their scientific research, professional and pedagogical work. We also offer the general public access to our collections of materials and information resources.

Our vision is to perform work professionally, quickly and efficiently, in close connection with the needs of our users. We strive to cooperate with partner institutions and follow the latest guidelines of the librarian profession within the framework of the national library information and research system.

Head: Metka Ljubešek, univ. dipl. bibl. in soc. kult.

Library collection and access to electronic resources

The library's professional work started at the beginning of the institute's establishment, enabling us to keep a rich library collection. This includes monographic and serial publications, standards and other regulations from the wider field of construction and for similar natural and technical sciences. Today we provide an extensive and high-quality collection of printed and electronic publications.

We strive to provide access to as many scientific and professional publications and relevant electronic resources as possible, which enables our users to access the latest information in their field. With consortium integration in the acquisition of international scientific literature, we follow the modern concept of scientific information. We have membership with CTK consortia through services such as ScienceDirect and SpringerLink, thus providing our users with access to full-text electronic resources and the possibility to publish in open access free of charge in publishers' hybrid journals.

Active member of the COBISS system - Co-operative Online Bibliographic System & Services

We have been a full member of the national library information system for almost three decades. With the collection of library materials and the bibliographies of ZAG's researchers and experts, we are actively building a COBIB union bibliographic and catalogue database, which is updated daily. In addition, we also offer a range of other services within the framework of the COBISS system and provide access to multidisciplinary bibliographic databases with citation indexes.

Active member of the DiRROS repository - Digital repository of Slovenian research organizations

For the past two years, we have actively devoted ourselves to publishing in the institutional repository DiRROS, where we provide access to electronic versions of scientific and professional works, publications, publishing activities, research data, and other research results created by ZAG employees. This also ensures that the achievements of our researchers are widely accessible and visible both to the scientific community and the general public.

Supportive environment

Head: dr. Urška Kropf, univ. dipl. inž. živil. tehnol.

We recognised the importance of quality support for the research process here at ZAG over a decade ago and started planning changes in the organisation of the support environment accordingly. Over the last five years, we have created two new units and renamed certain units to better capture the scope of the work carried out by each service.

When planning the organisational changes and introducing new areas of work in the Administrative Sector, we drew on the guidelines for the European Research Area, as some of the main guiding principles of ZAG are to foster research excellence, recruit excellent researchers, and provide quality support for their work. With this in mind, we applied for an ERA Chair project at ZAG in the latter half of the last decade. The FRISSBE project also represents an important turning point for the Administrative Sector at ZAG. With the funds from this project, we have been able to strengthen the staffing of the Public Relations Service, the Legal and Human Resources Unit, the Secretariat, and the Knowledge Transfer Service, and have established a bilingual working environment. The numerical strengthening of the Administrative Sector has coincided with the overall growth of ZAG, yet the number of people in the Administrative Sector as a proportion of all staff has increased from 14% to 17% over the past 10 years. The change in generations and the high number of retirements over the last five years have led to a reduction in the average age of staff in the Administrative Sector by 4 years, while the education level has risen sharply.

With the Research and Innovation Act (ZZrID), which came into force in 2022, all public research institutions were given the autonomy to manage their stable funding. ZAG allocates part of the so-called Development Pillar (RSF) to strengthening support activities - more specifically the quality, openness and transfer of knowledge, the promotion of science and community involvement. These funds are used to organise training courses to improve the competencies of researchers and support staff in various fields, including project management, intellectual property management, the promotion of science and artificial intelligence.

This year, the Slovenian Research and Innovation Agency (ARIS) is adopting a general act on the evaluation and implementation of stable funding for scientific research, which sets out three evaluation criteria. The Administrative Sector make an important contribution to the Viability criterion (sometimes referred to as *Vitality and Sustainability*), in the following areas:

- the quality of human resource management, staffing structure and equal opportunities
- respect for the implementation of open science
- the effectiveness of knowledge transfer measures
- the quality of scientific communication
- the quality of administrative and management structures, processes and business support

We were already conscious of the need for development in these areas, so are now embarking on further activities with all the more impetus. In 2021, the Administrative Sector developed a Gender Equality Plan (GEP), which has since been reviewed and updated annually. This enables researchers to participate in Horizon calls, while actively responding to the needs of our staff. The gender structure at ZAG has been well-balanced for many years, so we are focusing more on other areas where progress can be made. More and more employees are able to better and more easily balance their work and private life by being able to work

from home. The introduction of a bilingual working environment allows for the equal integration of foreigners into the ZAG working environment. The Welcoming Committee facilitates the recruitment and integration of foreigners into both ZAG and the Slovenian environment.

2020	**The epidemic of Covid-19** Establishing work at home for employees (also in the administrative sector)
2021	project FRISSBE - introduction of a bilingual working environment Action plan for gender equality Establishment of the Knowledge Transfer Service
2022	**Scientific Research and Innovation act (ZZrID)** Strengthening of the Human Resources Service - career plans and committee for the reception of foreign employees Strengthening of the Public Relations Service Strengthening of the ZAG Library
2023	**Regulation on Open Science** Project ROAD3P - strengthening of the Project Support Office Project SPOZNAJ
2024	Project KTO3 - strengthening of the Knowledge Transfer Service Strengthening of the ZAG Library - data manager Strengthening of the Legal Service

In September 2021, we established a Knowledge Transfer Service, which continues to strengthen in terms of its staff. Due to our cooperation with stakeholders, and the many innovations and inventions we successfully transfer to the economy, the area of intellectual property management is of great importance to ZAG. Civil engineering is an applied science at its core and ZAG has always helped to address current challenges in society.

Strengthening the Human Resources Service has enabled us to gradually introduce career development planning for ZAG employees - both researchers and support staff - from 2022 onwards. Following the strengthening of the Legal Service, we have also been very successful in obtaining investment funds for the construction of new buildings and the renovation of existing ones. Our own Maintenance Service is of great importance in the implementation of construction works.

We have developed and implemented various software tools to support our business, using our own development team at the IT Centre along with the help of subcontractors. Many of these tools are accessible to ZAG staff via the ZAG portal and facilitate their daily work. We are proud of the fact that, during the COVID-19 epidemic, homeworking was successfully established for the majority of staff in a very short time.

In 2022, we recruited an additional Open Science Officer in the ZAG Library to actively ensure compliance with the 'Decree on the conduct of scientific research work in accordance with the principles of open science', which was adopted in 2023. In 2024 we are recruiting a Data Manager, who will promote the publication of research data in Open Access and set up databases at ZAG, thus acting as a bridge between the Library, the IT department and researchers.

By strengthening the Public Relations Service, ZAG has significantly increased its visibility and recognition in the Slovenian and international arena and raised the quality of scientific promotion. In recent years, we

have regularly organised Open Days to present ZAG's activities to the wider public and to strengthen our cooperation with businesses and research institutions.

The Main Office, the Secretariat and the Mail Room, as well as the Finance, Accounting and Purchasing Department, are extremely important parts of the common services that enable the smooth day-to-day running of the whole organisation. Our own large fleet of cars includes several specialist vehicles, allowing our staff to efficiently perform fieldwork.

Throughout the last decade, the Project Support Service has assisted researchers in obtaining and carrying out research projects and implementing innovations stemming from the ZZrID, related sub-legislative acts, and the Resolution on the Scientific Research and Innovation Strategy of Slovenia 2030 (REZRIS30).

Unlike over the previous five-year period, the Joint Services collaborators now apply for and implement their own projects. These projects represent an important financial resource and allow employees to strengthen their numbers and add value in terms of the development of knowledge. Staff competencies are also strengthened through individualised training plans, as well as through regular in-house training. In this way, we offer quality support for the research process and make an important contribution to the viability of ZAG.

The Quality Management Service is an independent unit and is not part of the ZAG's administrative services, but it is an important part of the institution's support environment. Together with all employees, it ensures that the various certifications and accreditations (ISO 9001, ISO/IEC 17025, ISO/IEC 17065) and authorisations (Notified Body) are obtained and maintained. ZAG is also the proud holder of the Socially Responsible Employer certificate since 2022. We combine all the requirements into an integrated quality system, while constantly striving to keep the administrative structure as simple as possible and to optimise work processes.

ZAVOD ZA
GRADBENIŠTVO
SLOVENIJE

SLOVENIAN
NATIONAL BUILDING
AND CIVIL ENGINEERING
INSTITUTE

Dimičeva ulica 12
1000 Ljubljana
Slovenija

info@zag.si
www.zag.si