CoMS_ 2020/21

Construction Materials for a Sustainable Future

Book of Abstracts and Programme

2nd International Conference CoMS 2020/21

20-21 April 2021
Online Conference

Slovenian National
Building and Civil
Engineering Institute,
Ljubljana 2021

CoMS_2020/21 Construction Materials for a Sustainable Future

2^{nd} International Online Conference

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Slovenia,
April 20–21, 2021

Slovenian National Building and Civil Engineering Institute,
Ljubljana 2021

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Tuesday, April 20, 2021

8:30 – 9:00	30 min	REGISTRATION		
		PLENARY STAGE		
9:00 – 9:15	15 min	**Opening ceremony** Aleš Žnidarič, PhD, Slovenian National Building and Civil Engineering Institute, Director Tomaž Boh, PhD, Ministry of Education, Science and Sport, General Science Directorate, Director Patrik Kolar, PhD, European Climate, Infrastructure and Environment Executive Agency (CINEA), Head of Department C (Green Research and Innovation)		
PLENARY 1 9:15 – 10:05	25 min	PLENARY SPEAKER Ueli Angst, PhD, ETH Zürich, Switzerland: Size effects in corrosion of steel in concrete		
	25 min	PLENARY SPEAKER John Provis, PhD, The University of Sheffield, United Kingdom: Alkali-activated materials – from talk to action		
10:05 – 10:15	10 min	BREAK		
		BLUE STAGE	**GREEN STAGE**	**YELLOW STAGE**
10:15 – 11:05	**SESSION**	**Innovations in materials and technologies** (moderator Andraž Legat, PhD)	**Sustainable design** (moderator Friderik Knez)	**Recycling and circular economy** (moderator Vesna Zalar Serjun, PhD)
	20 min	KEYNOTE SPEAKER Karen Scrivener, PhD, Switzerland: Limestone calcined clay cements: progress in implementation and understanding mechanisms	KEYNOTE SPEAKER Andreja Kutnar, PhD, Slovenia: Wood as a building material for sustainable construction	KEYNOTE SPEAKER Ana Mladenovič, PhD, Slovenia: Establishing circular economy practices in the construction sector in Slovenia
	15 min	Electromagnetic fibre alignment to optimize the fibre utilization of ultra -high performance concrete (UHPC), Martin Schneider, Austria	Challenges in LCA of existing building, Tajda Potrč Obrecht, Slovenia	Materials and design principals for a Circular, Bio-based construction industry, Barrie Dams, United Kingdom
	15 min	On the use of metallurgical slags alternative to blastfurnace slags in the formulation of alkali-activated binders, Maurizio Bellotto, PhD, Italy	Renewable Materials in Buildings for Occupant Wellbeing and Performance, Michael Burnard, PhD, Slovenia	Reactivity of Siliceous Fly Ashes, Anya Vollpracht, PhD, Germany
11:05 – 11:20	15 min	BREAK		
11:20 – 12:05	15 min	Industrialization of an alkali-activated slag binder: solving the issues of early strength and superplasticizer efficiency, Luka Zevnik, PhD, Slovenia	Pavement-Watering Applied to Traditional and Cool Pavement Structures, Martin Hendel, PhD, France	Sustainable pre-treatment of wood biomass ash for partial cement replacement, Karmen Kostanić Jurić, Croatia
	15 min	Using Bacteria for Early Age Strength Improvement of Concrete, Lorena Skevi, United Kingdom	LCA and LCC assessment of UHPFRC application for railway steel bridge strengthening, Aljoša Šajna, PhD, Slovenia	FLAME - Fly Ash to Valuable Minerals: Upscaling of A New, Dry Classification Technology for Recovery of Performant Cementitious Materials, Ruben Snellings, PhD, Belgium
	15 min	Effect of crystalline admixtures on self-healing, Lina Ammar; France	ECOroads (Economical COncrete roads), Johannes Horvath, PhD, Germany	Mud From the Sitarjevec Mine as a Pigment for Textile Printing, Darja Rant, PhD, Slovenia
12:05 – 13:15	70 min	LUNCH BREAK		
		PLENARY STAGE		
PLENARY 2 13:15 – 14:05	25 min	PLENARY SPEAKER Alexander Passer, PhD, TU Graz, Austria: Sustainable Construction – New Chances for our Future?		
	25 min	PLENARY SPEAKER Kristina Mjörnell, PhD, Research Institutes of Sweden, Sweden: Estimation of presence of hazardous substances in the existing building stock using machine learning on building specific data		
14:05 – 14:15	10 min	BREAK		
14:15 – 15:05	**SESSION**	**Innovations in materials and technologies** (moderator Lidija Korat, PhD)	**Energy efficiency** (moderator Andreja Kutnar, PhD)	**Inspection, monitoring, assessment and repair** (moderator Irina Stipanović, PhD)
	20 min	RILEM TC 267-TRM Report: Optimisation of R3 Reactivity Test, Most Promising Method for Supplementary Cementitious Materials, Diana Londono-Zuluaga, PhD, Switzerland	KEYNOTE SPEAKER Sabina Jordan, PhD, Slovenia: Energy efficiency of buildings in the context of sustainability	KEYNOTE SPEAKER Andrej Anžlin, PhD, Slovenia: Inspection and monitoring of bridges to support the management activities of critical infrastructure
	15 min	Influence of Density on Tensile and Compressive Properties of Polyurethane Foam, Paulina Krolo, PhD, Croatia	Consumption and potential energy savings in the office building, Arta Sylejmani, Kosovo	Inspection, Assesment and Repair of Fire Damaged Concrete Structure, Meri Cvetkovska, PhD, North Macedonia
	15 min	Sustainable insulating composite from almond shell, Filip Brleković, Croatia	Thermal bridge assessment in prefabricated ventilated façade systems with recycled aggregates, Mergim Gaši, Croatia	Comprehensive permanent remote monitoring system of a multi-span highway bridge, Doron Hekič, Slovenia
15:05 – 15:20	15 min	BREAK		
15:20 – 16:05	15 min	Mode of operation of bio-based polymers for the control of fresh concrete properties, Wolfram Schmidt, PhD, Germany	The impact of building zone elements on airtightness, Sanjin Gumbarević, Croatia	Corrosion-cracking parameter in the concrete structure and impact in reinforced steel bars, Mihrie Bajoku, Croatia
	15 min	Mechanical Properties of Concrete Containing Wood Biomass Ash, Jelena Šantek Bajto, Croatia	Street furniture design as a means to mitigate urban heat island phenomenon: A case study, Andrej Bernik, France	Monitoring of steel corrosion in concrete exposed to marine environment, Miha Hren, PhD, Slovenia
	15 min	Effects of Waste Glass in Properties of Concrete, Naser Kabashi, PhD, Kosovo	Effects of energy renovation measures implemented on a residential building, Jože Hafner, PhD, Slovenia	Migratory Corrosion Inhibitors Technology for Improving Durability of Europe's Bridges Infrastructures, Ivana Lipoščak, Croatia

Wednesday, April 21, 2021

9:00 – 9:10	10 min	REGISTRATION		
		PLENARY STAGE		
PLENARY 1 9:10 – 10:00	25 min	PLENARY SPEAKER Andreas Rogge, PhD, BAM Federal Institute for Materials Research and Testing, Germany: Future Challenges in Construction Engineering		
	25 min	PLENARY SPEAKER Erik Schlangen, PhD, Delft University of Technology, The Netherlands: 3D-printing for construction at different scales		
10:00 – 10:10	10 min	BREAK		
		BLUE STAGE	**GREEN STAGE**	**YELLOW STAGE**
10:10 - 11:00	**SESSION**	**Digitalization and automation** (moderator Andrej Anžlin, PhD)	**Material – environment interaction** (moderator Miha Hren, PhD)	**Construction, maintenance and modelling** (moderator Aljoša Šajna, PhD)
	20 min	KEYNOTE SPEAKER Ksenija Marc, Slovenia: Implementing BIM in Slovenian Public Sector	KEYNOTE SPEAKER Marijana Serdar, PhD, Croatia: The importance of understanding microstructure of alternative binders to predict their durability	KEYNOTE SPEAKER Irina Stipanović, PhD, Croatia: Predictive maintenance planning for concrete structures
	15 min	Designing generatively to achieve an efficient and optimised solution, Gradišar Luka, Slovenia	Measurement of the chloride resistance of Environmentally friendly and Durable conCrete, Alisa Machner, Germany	Ductility of Hybrid FRP – Steel Reinforced Concrete Sections, Tvrtko Renić, Croatia
	15 min	Extending BIM for Air Quality Monitoring, Michael Mrissa, PhD, Slovenia	Sulfate resistance of cement with different volumes of fly ash, Toni Arangjelovski, PhD, North Macedonia	Flexible polymer connections for CLT structures, Boris Azinović, PhD, Slovenia
11:00 – 11:15	15 min	BREAK		
11:15 – 12:00	15 min	BIM application in civil engineering projects, Marina Davidović, Serbia	Comparative Study Selected Properties of Three Binders: Ordinary Portland Cement, Calcium Sulfoaluminate Cement and Alkali Activated Material Based Mortars, Ivana Vladić Kancir, Croatia	Fibre Reinforcement - the Key to Sustainable Reinforced Concrete Structures, Darko Nakov, PhD, North Macedonia
	15 min	Education for zero energy buildings using BIM, Bojan Milovanović, PhD, Croatia	Sulfate Resistance of Concrete after Two Years Exposure to Aggressive Solutions, Vesna Bulatović, Serbia	Experimental and numerical investigation of restrained shrinkage of concrete, Lucija Hanžič, PhD, Slovenia
	15 min	Characterization of the reaction degree of slag in a cement by neural networks based electron microscopy image analysis, Priscilla Teck, Belgium	Effect of Chemical Admixtures on Corrosion Behaviour of Structural Steel in Mortar: Comparison between Standardized and Alternative Method, Kiran Ram Porikam Poil, Croatia	Seismic Strengthening of Stone Masonry Structures – State of the Art, Ivan Hafner, Croatia
12:00 – 13:00	60 min	LUNCH BREAK		
13:00 – 14:00	**SESSION**	**Digitalization and automation** (moderator Lucija Hanžič, PhD)	**Material – environment interaction** (moderator Nina Gartner)	**Construction, maintenance and modelling** (moderator Marijana Serdar, PhD)
	15 min	Novel Cementitious Materials for extrusion-based 3D printing, Richard Ball, PhD, United Kingdom	Study on mechanical and durability properties of concrete with RTPF after high temperature exposure, Marija Jelčić Rukavina, PhD, Croatia	Numerical Modelling of Concrete Beam Reinforced with FRP Bars Subjected to Bending Until Failure, Tomislav Kišiček, PhD, Croatia
	15 min	Temperature pre-treatment of gypsum for powder based 3D printing technology, Vesna Zalar Serjun, PhD, Slovenia	Effect of Binder Composition on Carbonation Resistance of Sustainable Concrete Formulations, Ognjen Rudić, Austria	Evaluating the impact of age on the behaviour of SFRC during flexural loading, Jakob Šušteršič, PhD, Slovenia
	15 min	Development of sustainable lightweight 3D printing mixtures for 3D printing, Pawel Sikora, PhD, Poland	Steel reinforcement in slag containing binders and its susceptibility to chloride-induced corrosion, Shishir Mundra, PhD, United Kingdom	Modelling the durability of novel cementitious materials exposed to the drying and carbonation, Yushan Gu, PhD, France
	15 min	3D multi scale imaging in additive manufacturing, Lidija Korat, PhD, Slovenia	Influences of the combined application of polysaccharides and superplasticizers on early hydration of cement, Alexander Mezhov, PhD, Germany	Flexural Behaviour of High Strength Concrete with Steel and Polypropylene Fibers, Natalija Bede, PhD, Croatia
14:00 – 14:15	15 min	BREAK		
		PLENARY STAGE		
14:15 – 15:15	60 min	**Panel discussion** Kristina Mjörnell, PhD, Research Institutes of Sweden Andreja Kutnar, PhD, InnoRenew CoE & University of Primorska Erik Schlangen, PhD, Delft University of Technology, The Netherlands: 3D-printing for construction at different scales Friderik Knez, Slovenian National Building and Civil Engineering Institute Aleš Ugovšek, PhD, moderator		
15:15 – 15:30	15 min	Closing		

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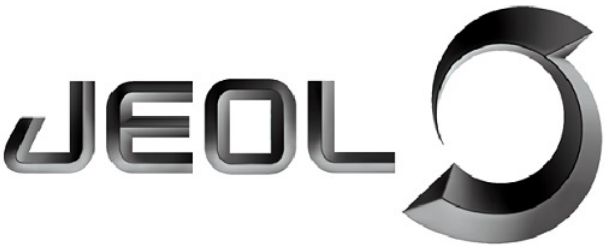

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Chair: Aljoša Šajna

PLENARY LECTURES' ABSTRACTS

Plenary Lectures

Tuesday Morning Plenary Talks
Apr 20, 9:15 - 10:05

PL-01
Size effects in corrosion of steel in concrete
Ueli Angst
ETH Zurich, Switzerland

Predicting the corrosion performance of reinforced concrete is essential to ensure durability, safety, cost-efficiency, and sustainability of new and existing concrete structures. The traditional concepts in both carbonation and chloride exposure environments are based on transport models to predict the penetration of the carbonation front or the chlorides through the concrete cover until a certain limit state is achieved. In these conceptual service life predictions, the corrosion propagation stage is generally – in a conservative manner – not considered. This contribution explores novel concepts to forecast both corrosion initiation and propagation in carbonation and chloride exposure environments. These concepts are based on recent converging research advances in the field of corrosion and electrochemistry of steel in concrete (or porous media in general), which can essentially be regarded as questions of "size effects".

PL-02
Alkali-activated materials – from talk to action?
John Provis
University of Sheffield, Department of Materials Science and Engineering, United Kingdom

There has been an enormous growth in the volume and scope of technical analysis of alternative cements, including alkali-activated materials, during the past decade. Some of this growth has been accompanied by "real-world" actions in terms of commercialization, trials, and deployment. However, there are a very large number of lines of investigation – some of which appear extremely promising from environmental and technical perspectives – that have not yet been translated into reality. This presentation will address some of the key drivers for innovation in cement technology, with a particular focus on alkali-activated materials, including comments on the pathways by which some of the evident potential of these materials can be unlocked for the benefit of society.

Plenary Lectures

Tuesday Afternoon Plenary Talks
Apr 20, 13:15 - 14:05

PL-03
Sustainable Construction – New Chances for our Future?
Alexander Passer
Graz University of Technology, Austria

Climate change presents the single biggest threat to sustainable development everywhere and its widespread, unprecedented impacts. While the construction sector including buildings is responsible for approximately 40% of Europe's energy consumption and 36% of CO2 emissions, making it the single largest cause of energy consumption and GHG-emissions, it also holds huge potential for improvement. However, urgent actions are needed to cut energy consumption and GHG-emissions caused in construction product industry as well as in the construction, facilities management and real estate sectors. Therefore, the reduction of life cycle related carbon footprint of construction works shall become an imperative. The keynote will address the latest methodological, technological and policy related developments as well as presents good examples that already show that it is feasible to create a net-zero GHG-emission built environment. In addition to addressing climatic and environmental concerns, these projects also engage with wider societal concerns expressed in the UN Sustainable Development Goals (SDGs). These positive examples are proof of technical, social and economic feasibility. There is an imperative to adopt these practices widely.

PL-04
Estimation of presence of hazardous substances in the existing building stock using machine learning on building specific data
Kristina Mjornell
Research Institutes of Sweden, Sweden

The research group has developed methods for predicting characteristics in multi-family buildings using machine learning methods on large-scale data from the Swedish building stock. The predicted results have been used as input to get better cost estimates for renovation strategies in the building stock. Hazardous substances are typically observed during the actual renovation, and can increase the renovation costs several fold. So, knowing this information beforehand is advantageous when deciding on appropriate renovation measures. Machine learning tools have not yet been used to automate predictions for the presence of hazardous materials in building components before. The absence of centralized storage of environmental inventories and decommissioning inventories is a crucial reason. Sweden is unique in terms of the requirements for carrying out environmental inventories and demolition inventories prior to rebuilding and demolition. Unfortunately, this information has only been stored by property owners and urban construction offices and environmental administrations and not at national level. In this project, important is done to collect and systematize observations to make them useful for machine learning.

Plenary Lectures

Wednesday Morning Plenary Talks
Apr 21, 9:10 - 10:00

PL-05

Future Challenges in Construction Engineering

Andreas Rogge

Bundesanstalt für Materialforschung und -prüfung in Berlin, Germany

Productivity and sustainability are key factors for the technical development of the construction sector during the next decades. Only a corresponding, goal-oriented and efficient combination of specifically developed construction materials and techniques based on innovative digital technologies and ideas will contribute to the huge societal challenges of the future. On a material level, sustainability in concrete production stands for the use of alternative binders, aggregates and reinforcing fibres in combination with bio-based additives to produce robust mixtures with a minimized CO2-footprint. On a constructional level, the focus will be on reducing manpower on site by automated techniques like additive manufacturing and by an increased use of prefabricated elements up to modular room cells, accompanied by innovative methods for the re-use of constructional elements, reduction of supplementary constructions and digitally optimized site logistics. This presentation will discuss recent developments in these fields, as well as upcoming ideas.

PL-06

3D-printing for construction at different scales

Erik Schlangen

Delft University of Technology, Netherlands

3D printing is the new method for construction of concrete elements and structures. The material to be used for printing is completely different than the conventional concrete for construction. Designing and optimising materials for this purpose with excellent properties during printing, but also in the final product is still a challenge. Different approaches leading to different final products will be presented as well as methods for improving ductility of the printed material and increasing bond strength between the layers. 3D printing can also be used on a smaller level by printing fibres or micro-reinforcement or creating material shapes and structures with special properties. Several ideas for this will be discussed. Final aspect that will be presented is the use of printing to create smart structures by adding sensing or self-healing capacity to a structure in certain location.

ORAL PRESENTATIONS' ABSTRACTS

Innovations in materials and technologies

Tuesday Morning Track A - S1
Apr 20, 10:15 - 11:05

OR-01

Limestone calcined clay cements: progress in implementation and understanding mechanisms

Karen Scrivener

Laboratory of Construction Materials, Ecole Polytechnique Federal de Lausanne (EPFL), Lausanne, Switzerland, Switzerland

Limestone calcined clay cement present an enormous potential to lower the embodied CO2 of cementitious materials. In the presentation recent progress toward implementation and also in understanding the durability of these materials will be discussed.

OR-02

Electromagnetic fibre alignment to optimize the fibre utilization of ultra-high performance concrete (uhpc)

Sandra Ofner[1], Manuel Megel[2], *Martin Schneider*[1], Carina Neff[2]

[1]Carinthian University of Applied Sciences, Austria

[2]Kaiserslautern University of Applied Sciences, Germany

As UHPC itself is a very brittle material, steel fibres are usually used to get a more ductile behaviour. Because of the viscosity of the UHPC matrix in its fresh state, the steel fibres follow the direction of the filled in concrete and, as a result, they are more or less randomly oriented, which means that only a small amount of them are aligned in the needed direction to absorb tension stresses. Due to that fact, it is difficult to predict the behaviour of UHPFRC components while loading because only a small amount of fibres can be taken into account for designing the structure. Furthermore, it is not efficient and in particular not ecological to insert more steel fibres as needed to achieve the desired result. Concerning this, an existing approach is to align the steel fibres in the fresh liquid UHPC with magnetic fields. This proceeding can lead to an increasing of the material efficiency. The focus of the present case study is to align steel fibres in UHPFRC members and in subsequently added strengthening layers.

OR-03

On the use of metallurgical slags alternative to blastfurnace slags in the formulation of alkali-activated binders

Maurizio Bellotto[1], Luka Zevnik[2]

[1]Polytechnic of Milano, Milano, Department of Chemistry, Materials and Chemical Engineering, Italy

[2]LZ Concrete, Leonardo d.o.o., Slovenia

Alkali-activated blastfurnace slags can be used for the formulation of one-part binders for the production of load-bearing structures replacing conventional Portland cements. The European production of blastfurnace slag sums to about 24.5 Millon Tons (Euroslag, 2016). More than 80% is used for the production of cement and concrete. The remainder is not quenched, and is therefore not a suitable pozzolanic addition. Thus, no blastfurnace slag is left for alkali-activated binders. Moreover, the cost of ground granulated blastfurnace slag (GGBS) is higher than the one of CEM II cement, the most widespread in Europe, making alkali-activated binders not commercially attractive.

It is therefore necessary to find alternative sources of slags which may constitute additional volumes of low-priced material. The first choice is the use of foundry cupola-furnace slag, whose composition is quite similar to GGBS. Its actual composition differs according to the quality of pig-iron produced, and it may show higher Mg contents in the case of spheroidal pig iron. The observed different reactivity is due to the different pore solution chemistry and nucleation kinetics, which can be accounted for with the addition of reactive silica and soluble Ca2+ containing species.

Another important source of slag is the ladle refining of steel, which accounts for the production of 4 Million Tons of white slag in Europe, presently entirely landfilled. This slag is richer in calcium with respect to GGBS, making it difficult to quench and granulate. We have performed tests adding a silicon bearing material (silica sand, foundry samd) to the molten slag in the ladle to modify is composition and make it suitable for quenching and granulation. The material which is produced is as reactive as GGBS and is a suitable candidate for the production of alkali-activated slag binders.

Sustainable design

Tuesday Morning Track B - S2
Apr 20, 10:15 - 11:05

OR-04

Wood as a building material for sustainable construction

Andreja Kutnar

InnoRenew, Slovenia

Forests play a crucial role in the global carbon cycle and the fight against climate change. Wood products can contribute to climate change mitigation as they act as a carbon pool during their service lives, as they withdraw CO2 from its natural cycle, as wood products can substitute for more energy-intense products after their service life.

In this presentation the need for research and innovation activities leading to new business opportunities will be discussed. How to improve the re-usability and recyclability of wood composites and construction material will be presented. Efficient resource use is the core concept of cascading, which is a sequential use of a certain resource for different purposes. This means that the same unit of a resource is used for multiple high-grade material applications (and therefore sequestering carbon for a greater duration) followed by a final use for energy generation and returning the stored carbon to the atmosphere.

Intelligent concepts for reuse and recycling of valuable materials at the end of single product life will reduce the amount of waste to be landfilled. Furthermore, we should develop systems for wooden buildings allowing for easy dismantling and remounting. Examples of the development of environmentally-friendly additives and impregnating agents for wood products will be presented.

OR-05

Challenges in LCA of existing building

Tajda Potrč Obrecht[1], Sabina Jordan[1], Andraž Legat[1], Roman Kunič[2]

[1]Slovenian National Building and Civil Engineering Institute, Slovenia

[2]FGG, Slovenia

The existing building stock is responsible for a large share of the European CO2- eq emissions. Because a large share of the building that will be occupied in 2050 is already built, it is crucial that building will be renovated in order to be able to meet the sustainable development goals proposed by UN. The EU is encouraging their member state to increase the renovation share up to 2-3 % of the building stock per year while the current renovation rate is 1.2 %. To assess the benefits of the renovation the environmental impacts should be assessed. Life Cycle Assessment is a methodology is a recognized methodology for assessing the impacts but it is mainly applied to new buildings at the start of their life cycle. There are certain differences when we are assessing buildings that are in the middle of their life cycle or before the renovation. For example, if we want to know what the residual value of the building materials is, we have to find ways how to determine the environmental impacts of materials that were produced in the past? During the research we have found out that it is important that the datasets are remodeled in a way that enables fast changing of the parameters that are connected with energy flow in the dataset, since these are the parameters that had changed the most during the recent period. Also, we need to know how much the service life of a building material can influence the results. There are several inputs that have to be retaught when we are assessing existing buildings. This is crucial, because only a harmonized and robust method of evaluating the environmental impacts of building will serve as a background to further stimulate the building renovation.

OR-06

Renewable Materials in Buildings for Occupant Wellbeing and Performance

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The environments we spend time in impact our wellbeing and performance in a variety of ways. Accordingly, it is critical to investigate how building design affects occupant wellbeing, as we spend most of our time indoors. Previous investigations have revealed that a variety of psychophysiological, affective, and cognitive effects may be caused by interacting with wood. These effects can influence emotional wellbeing, stress levels, work performance, musculoskeletal health, comfort and other aspects of human health. These benefits are amplified by the sustainability and performance benefits of wood construction. The InnoRenew CoE Human Health in the Built Environment research group explores human wellbeing and performance in relation to building design, material selection, use patterns, and overall indoor environmental quality. This presentation will include an overview of recent and ongoing research investigating human health in buildings at the InnoRenew CoE. Topics including how wood furniture in offices effects stress, cognition, and mental wellbeing, the design and performance of ergonomic furniture from wood, school furniture mismatches, the relationship between thermal properties of desktop materials and human comfort, and other studies. Finally, perspectives on converting these research findings to actionable design strategies to support renovation and new construction that merges health and sustainability will be presented.

Recycling and circular economy

Tuesday Morning Track C - S3
Apr 20, 10:15 - 11:05

OR-07

Establishing circular economy practices in the construction sector in Slovenia

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In Slovenia, the recycling practices in construction sector started in the 1970's, when Siemens-Martin furnace slag aggregate was used to a large extent for road construction. Because of unsuitable use of this material, many roads began to show damage, resulting in economic costs. We learnt a lot from this failure and from the current perspective this failure is considered as a step out of the comfort zone. Since then a lot of knowledge has been gained and a lot of effort has been put into promotion of recycling in construction sector. As a consequence many vivid recycling activities on different types of waste have been already established as a successful daily business. Among them are steel slags, C&D waste, incineration residues, sewage sludge, etc. Immobilization procedures are frequently used in case that treated waste is not environmentally inert. All these recycled waste-based materials are legally put on the market with the Declaration of Conformity, which is based either on the Construction Product Regulation either on the Slovenian Technical Approval.
In this moment economic benefit of partners in the waste holder – recycling plant – final user value chain are the main drivers of such practices. The paradigm »Everything

that can be recycled should be recycled« is moral imperative rather than economic logic, since in many cases recycling is still more expensive than landfilling. Therefore these ethical dilemmas should come to the agenda for future incentives and regulation on the national level.
There are some other issues that hinder the recycling, e.g. the problems occurring in transition of recycling technology from laboratory scale to production scale, variations in waste properties and disturbances in waste supply chain. On top of that, a strong opposition of civil society against waste recycling opens a new field of activities, in which securing and holding the Social Licence to Operate would be the main prerequisite for beneficial, sustainable...

OR-08
Materials and design principals for a Circular, Bio-based construction industry

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The construction industry has traditionally operated with linear economy principals, with buildings being demolished rather than recycled following the end of the design life. The industry can play a major role in reducing requirements for valuable natural resources and promoting sustainable design and construction by adopting practices adhering to circular economy principals. Central to this would be the use of renewable bio-based construction materials and designing buildings for disassembly - with a buildings' elements and connecting components designed to be reused, rearranged in a different configuration or recycled following the expiration of the buildings' initial functional use.
The Circular Bio-based Construction Industry (CBCI) project team have conducted reviews and evaluations concerning the current range of bio-based loadbearing, insulation and façade materials and reversible designs. The significance of this research is the determination of suitable materials and construction systems for the creation of bio-based, sustainable and reversible wall panels and modular units for living laboratories.
Alongside materials such as timber, there are emerging technologies and 21st century innovations. Key considerations are the extent to which non-organic constituents - included to improve mechanical properties and durability - may be added to materials so that the finished products may still be disassembled and reused at the end of the buildings' initial function. The compatibility of construction methods with the concept of designing for disassembly is discussed. Structural and logistical elements of design are evaluated along with protocols concerning reversibility. Simple design, minimal material variation, transparent and accessible mechanical connections and the off-site prefabrication of units, panels or linear elements are all compatible with circular economy design.
Acknowledgement: The Circular Bio-based Construction Industry (CBCI) project is funded by the European Union Regional Development Fund Interreg 2 Seas Mers Zeeen (2S05-036).

OR-09
Reactivity of Siliceous Fly Ashes

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Siliceous fly ash is a supplementary cementitious material (SCM) often used in the production of cement and concrete because of its pozzolanic reactivity. Furthermore the replacement of Portland cement by fly ash reduces CO2 emissions and energy consumption. The knowledge of its chemical, mineralogical and physical properties is vital to understand and to predict its behaviour in a cementitious environment. The influence of these properties on the reactivity of siliceous fly ashes was examined using a broad variety of commercial fly ashes. The reactive potential was analysed by relative mortar strength and the recently proposed R^3 rapid screening test. The R^3 heat calorimetry test has been designed to predict the contribution of a SCM to the hydration reaction in an artificial environment within a relatively short time. In this research, a mixture of the FA, portlandite, gypsum and KOH solution was used to simulate a cementitious environment. Statistical data analysis was performed to assess impact factors on the reactivity of the ashes. It can be concluded that the R^3 screening test is able to predict the reactivity, whereas the strength reactivity index is not a good measure to characterise the reactivity, because the influence of the interaction between cement and fly ash and granulometric effects overlap with the underlying actual potential of the fly ash. The R^3 test is able to measure the reactivity with high reproducibility independent of such interactions. It could be observed that the TiO2 content of the fly ash impacts its reactivity, whereas glass content or fineness show no correlation with the reaction heat (as well as with mortar strength). The research was conducted in connection with the work of the RILEM TC 267-TRM (Tests for Reactivity of Materials).

Innovations in materials and technologies

Tuesday Before Noon Track A - S4
Apr 20, 11:20 - 12:05

OR-10
Industrialization of an alkali-activated slag binder: solving the issues of early strength and superplasticizer efficiency

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The production of alkali activated binders as dry-premixed powders which hydrate and harden on mixing with water effectively widens up the ease and scope of application of such systems. However some issues must be tackled for enabling a wide scale commercial use of such binders. The most relevant are assuring an adequate early

strength, providing efficient superplasticizers and providing compatibility with the EN-197 prescriptions. We show a practical example of an industrial solution.
Activation by sodium carbonate alone gives a slow setting and hardening, and several options have been proposed in the past to accelerate it. We have chosen hydrated lime or clinker as the accelerating addition, to use the calcite precipitation equilibrium as the sink for carbonate ions in solution. The best performances in terms of early setting and strength development are obtained for equimolar additions of hydrated lime and sodium carbonate. When using clinker as the accelerating addition, it is possible to formulate a CEM III/C by allowing clinker 5 wt% and sodium carbonate 5 wt%.
A drawback of these systems is the lack of efficacy of conventional superplasticizers, with sugars and lignosulfonates behaving the best but showing only limited effect. This lack of efficiency can be related to the much lower Ca2+ concentration in the pore solution compared to Portland cement. To overcome this limitation we have tried sodium sulfate as an activator with Ordinary Portland Cement CEM I as the accelerating addition. We have also prepared similar blends with bypass condensation kiln dust as a replacement for sodium sulfate. Bypass condensation kiln dust is a mixture of potassium and sodium chlorides and sulphates. These systems are reactive and show excellent behavior with all conventional superplasticizers. Similarly to the above, CEM III/C cements can be formulated by allowing clinker 5 wt% and the activator 5 wt%.
With such a system (called ECOncrete) we have batched a concrete to cast an industrial flooring. The maximum aggregate size was 16 mm, with a water/binder ratio of 0.45. The compressive strength was 5 MPa at 1 day, 35 MPa at 7 days and 45 MPa at 28 days. The slab was 100 m 2 and was cast without shrinkage cuts, and yet no cracking has appeared after more than 1 year. Notwithstanding the high level of chlorides in the kiln bypass dust, no reinforcement corrosion has been noticed, and a very low chloride permeability has been measured on the manufact.

OR-11

Using Bacteria for Early Age Strength Improvement of Concrete

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Development of early age strengths of concrete structures is a crucial parameter in in-situ concrete casting affecting the time and therefore the cost of the construction process. A hindering factor for expanding the use of low-carbon cement is the initial lower strength gain that these materials present in comparison to Portland cement. Nonetheless, employing low-carbon cementitious materials is key for achieving sustainability in the construction industry. An unconventional way for improving the early age strength of concrete is by using bacteria. Several studies have demonstrated the enhancement of strength in concrete by the addition of bacteria cells. These results were attributed to the precipitation of calcite that is induced by the metabolism of the microbes. Here, a different approach to the phenomenon is attempted. In this paper, both live and dead bacteria were added directly in cement mortars in different concentrations. The effect of the bacterial addition on the hydration of cement pastes and the strength properties of mortars at 3, 7 and 28 days were studied. An increase in the strengths of most of the mortars containing bacteria was reported, which was more pronounced for the samples containing dead cells. No additional calcite formation was detected in the samples disproving earlier theories. Furthermore, the hydration rate of the cement was not significantly affected by the addition of the bacteria, either live or dead, suggesting that it is also not a nucleation effect. Microstructural analysis with Scanning Electron Microscopy (SEM) and Thermogravimetric analysis (TGA) were applied for interpreting the strength results and other hypotheses for the strength improvement are suggested. The addition of bacteria appears to be a cheap and environmental-friendly solution for enhancing the properties of low-strength sustainable cement-based materials, thus encouraging their wider use in constructions.

OR-12

Effect of crystalline admixtures on deformation and self-healing

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Reinforced concrete frequently presents cracks due to mechanical loadings or environmental conditions. By modifying the transfer properties of concrete, cracks affect the structure and material durability by making easier the penetration of aggressive agents (CO2, chloride, sulphate, etc.). Previous researches have proved that self-healing of cracks can limit this problem. Indeed, self-healing by reducing the crack size decreases significantly the concrete permeability and improves its durability. To accelerate this process, crystalline admixtures can be used to ensure an autonomous healing. Today, several types of crystalline admixtures are proposed on the market of construction materials. They are generally effective to limit concrete permeability and shrinkage. In the present research study, the deformation and healing capacity of mortars containing two types of crystalline admixtures are evaluated on a Portland cement mortar as well as their microstructure (porosity, hydration products). To monitor the healing process, specimens are pre-cracked at 28 day-old and stored under water. The evolution of the crack dimensions is measured by means of 2D optical microscope observations after 35 and 120 days of curing.

Sustainable design

Tuesday Before Noon Track B - S5
Apr 20, 11:20 - 12:05

OR-13

Pavement-Watering Applied to Traditional and Cool Pavement Structures

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The thermal behavior of 12 traditional and cool pavement structures (asphalt, granite, stabilized sand, cobblestones, reflective paints, pervious concretes, dry grass, etc.) is studied in the lab under heat-wave like conditions. Pavement-watering is applied and adjusted to each structure to maximize cooling and minimize water consumption using two linear cooling regimes. The surface heat budget is closely analyzed and used to estimate the partitioning of irradiance and net radiation into conductive, convective, radiative and cooling flux at surface. Energy partition, surface temperature increase and optimal watering rates all exhibit good correlation with an absorptivity index that includes the albedo and emissivity and their respective irradiance proportion in long and short-wave radiations. In-depth transmitted flux is also characterized versus a composite transmission index that includes the absorptivity index as well as the apparent conductivity of the material layers. Results from this work contributes to improving our understanding of the energy balance of cool pavements compared to traditional ones under specific weather conditions, as well as that of processes involved in the optimization of their evaporative cooling. Benefits of each pavement, efficiency of the method, limitations of the protocol and its potential transposition to the field are all discussed in this contribution.

OR-14

LCA and LCC assessment of UHPFRC application for railway steel bridge strengthening

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Most of the existing railway steel bridges are nowadays older than 70 years, experiencing serious aging and overload problems. Therefore they either need to be replaced or strengthened to fulfil the increased requirements. The main idea of strengthening existing steel bridges is considering the possibility of adding load bearing deck above the main girders without replacing them. In this particular case study, the original steel structure of the 9m long railway bridge was dismantled and transported to the laboratory for the experimental assessment and development of the new rehabilitation method. Based on the assessment results, a strengthening slab was designed using Ultra High Performance Fibre Reinforced Concrete (UHPFRC) formula. In the life cycle analysis, using LCC and LCA models, the comparison of the application of UHPFRC cast in-situ deck is compared to the bridge replacement solution, which was actually selected method by the owner. The executed solution used also a temporary bridge in order to enable continuous traffic, which has caused very high construction costs. In order to compare different options, we have additionally analysed a solution without a temporary bridge, which created three life cycle scenarios. Most important steps during the construction, exploitation and end-of-life stage have been taken into account and integrated into the LCA and LCC models. Finally the environmental, economy and societal impacts of three solutions were compared over the period of 60 years. The rehabilitation option with UHPFRC deck has shown by far the lowest direct and environmental cost while the user delay costs only after the period of 50 years are not the most convenient for users. Superior characteristics of UHPFRC enabled the optimization of the load bearing deck and by that a very low total used quantity of material resulting in minimum direct and indirect costs.

OR-15

Ecoroads

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Roads play a very important part in any nation's infrastructure. Their construction and maintenance, and the vehicles that travel over them, consume large amounts of energy. This energy use results in atmospheric emissions, the reduction of a non-renewable resource, and other environmental impacts. Any reduction of the lifetime energy use, even if only by a small percentage, will have significantly positive implications for sustainable development.
Concrete roads are durable and safe without defects like rutting, cracking, stripping, loss of texture, and potholes etc. This low maintenance requirement is one of the principal advantages of concrete pavements. There are well-designed concrete pavements that have required little maintenance well beyond their designed 30-year design lives.
Concrete pavements are well developed at Austrian Highways and Expressways, Rural Roads predominated by asphalt. Our objective in this new branch project is to transfer the technology from H&E to rural roads. Goal of this programme is to achieve more quality, improve value for money and provide a boost to innovation in road construction in Austria.

Recycling and circular economy

Tuesday Before Noon Track C - S6
Apr 20, 11:20 - 12:05

OR-16

Sustainable pre-treatment of wood biomass ash for partial cement replacement

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In July 2019, Croatian energy market operator had 38 contracts for electricity from renewable energy sources (RES) with power plants under construction. 50% of these were for biomass power plants and represented 19% of planned install power. While the increasing number of plants creates more wood biomass ash (WBA) to manage, landfilling prices are rising and although this research is done locally, the problem is global. In 1882 the first coal fired power plant was built in London as a project by Thomas Edison. The first high-volume coal fly ash recycles in concrete was done to repair a part of the Hoover Dam in 1942. In the 80s, with first legal guidelines and construction expansion, recycling of coal ash in concrete become routine. Biomass has been used as heat energy since people learned to control fire, but when speaking about RES, we refer to modern biomass combustion systems that started to sprout in developed countries during the 90s. Extensive research on the characterization of WBA and its influence on concrete properties has been going on during the last few years. Research has also been done on the impact of recycling for other fields trying to find a quicker solution for ash disposal this time. For now, we know that WBA can be used as an active (replacement of cement) or inactive (filler, sand substitute) concrete component. Fly WBA is usually compared with coal fly ash, but ash properties vary depending on many factors - from type and growth conditions, through the combustion system, to ash management on site. The link between power plants and the concrete industry should be established through consistency and quality control. This could be achievable by establishing ash pre-treatments. Treated ashes could be a more reliable material for larger scale cement replacement.

OR-17

FLAME - Fly Ash to Valuable Minerals: Upscaling of A New, Dry Classification Technology for Recovery of Performant Cementitious Materials

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New, performant processing technologies that recover valuable resources from low-grade by-products or wastes are key enablers in materializing a circular economy. In the FLAME project a new, dry, energy-efficient powder classification technology has been upscaled from small-scale laboratory (10 kg/h) to semi-industrial prototype (500 kg/h). The technology enables to extract ultrafine (d50 of 3-4 µm), fine (d50 of 10-20 µm) and medium or coarse (d50 > 30 µm) size fractions from dry mineral powders such as coal combustion fly ashes. The technology was validated for different scale prototypes and for a range of inorganic powders. The separation principle was confirmed by computational fluid dynamics simulations of air flow and particle trajectories. The produced classified materials were tested in relevant end-product applications. The ultrafine fraction extracted from fly ashes enables substitution of silica fume in high strength concrete, the fine fraction from fly ashes complies to requirements for use as cement and concrete constituent and improved the workability of self-compacting concrete. The coarse fraction was tested as a substitute filler in plastic composites and as an opening agent in ceramic bricks. Life cycle analysis indicated that the environmental impact of the FLAME classification process is subordinate to the reduction in environmental impact by substitution of primary raw materials or materials of high embodied energy such as Portland cement clinker in the end-products.

OR-18

Mud from the Sitarjevec Mine as a Pigment for Textile Printing

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SUMMARY: The Sitarjevec mine, located near the town of Litija (Central Slovenia), is recognized by the strong yellow colour of its dripstone structures and mine mud deposits. The mine mud, composed predominantly of goethite, accumulates on the ground of the mine shafts as the result of the interaction between percolating underground water, iron ore minerals and microorganisms. Since the accumulation of limonite mine mud is an ongoing process, larger quantities of mud have been deposited in the mine shafts since its closure. These deposits present a real threat of unleashing a mine mud spill on the town of Litija. Such a scenario has already previously occurred. In order to find new potential routes for recycling larger quantities of this mine mud, the present research work was performed to assess the use of mine mud as a pigment in the dye industry. In the first stage, the chemical (XRF) and microstructural (SEM) characteristics of the mine mud were defined together with the identification of its phase composition (XRD), particle size distribution and specific surface area (BET). Furthermore, the pigment was used to colour textile printing paste on a laboratory scale. To define the most appropriate quality of textile prints the rheological response of the various textile printing paste samples was investigated in terms of their plastic viscosity, indicating their suitability for use in textile printing. Test prints were conducted, and the properties of leaching and fastness in the prints were assessed.

Innovations in materials and technologies

Tuesday Afternoon Track A - S7
Apr 20, 14:15 - 15:05

OR-19

RILEM TC 267-TRM Report: Optimisation of R3 Reactivity Test, Most Promising Method for Supplementary Cementitious Materials

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Supplementary cementitious materials (SCMs) are commonly used in concrete practice nowadays, either in blended cements or as separate additions into the concrete mixture. The use of cementitious and pozzolanic by-products (fly ash and other artificial pozzolans, natural pozzolans, slag, limestone, …) is one way to obtain a more sustainable binder for the construction industry and there are also benefits related to costs and some durability problems. But there is an important lack of methods to assess the potential reactivity of a material for use as an SCM. In the round robin campaign on chemical reactivity test methods showed that the R3 reactivity test, using calorimetry and bound water, provides the most relevant indication of the reactivity of supplementary cementitious materials (SCMs), compared to other methods. In this second stage, the main aim was focus on improving the robustness of the protocol of the test. The influence of the mixing conditions, mix design, dying procedure and so on. As well as the repeatability and reproducibility of the final protocol.

OR-20

Influence of Density on Tensile and Compressive Properties of Polyurethane Foam

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Polyurethane (PU) foams are widely used in building structures. Due to their good thermal and sound insulation properties, PU foams are often applied in the production of façade systems as a non-structural component. In addition, they are commonly used in structural load-bearing components, e.g. as a core material in composite sandwich panels. In order to be used in load-bearing structures, it is necessary to know their mechanical properties. The main mechanical properties of PU foams are influenced by many parameters such as density, temperature, anisotropy, loading condition, etc. In this paper, the influence of density on tensile and compressive properties of PU foam is presented. Therefore, the uniaxial tension and compression tests according to the International Standards for six different densities were performed. Based on the test results, the influence of density on tensile and compressive strength as well as compressive modulus of elasticity is reported.

OR-21

Sustainable insulating composite from almond shell

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New generations of eco-friendly and sustainable insulating materials are prepared as composite materials in which the plant fibrous material (by-product of agricultural activity) is bonded by inorganic binders. In addition to good mechanical properties and low density, these composite materials also possess good insulating properties. In this paper the possibility of the preparation of composite material on the basis of almond shell with potential application as insulating boards has been studied. Composites from milled and sieved almond shells and wood-wool bonded with Portland cement and sodium silicate solution have been prepared. The hydrolytic properties, flexural strength, thermal properties, and calorific value of prepared composites were investigated.
Composites prepared with Portland cement alone had setting times greater than 24 h, and further test were carried out on composites prepared with the addition of sodium silicate solution as a binder. Optimal mechanical properties, density, and water glass consumption had composites prepared with almond shell particle size from 1,25 to 2,5 mm. Mechanical testing of samples with density of 0,503 g/cm3 showed that strain in range of 144-180 N causes a maximum deformation of 12 cm and the stress of 0,12 MPa causes irreversible deformation and cracking. Thermal conductivity of prepared composite was 0,203 Wm-1K-1 and its thermal diffusivity was 0,124 mm2s-1. Calorific value test showed slightly higher results than wooden materials with low sulphur and chlorine content. Examined mechanical and thermal properties of composite material are comparable to the properties of insulating materials available on the market. The advantage of such material is so-called binding of CO2, because by production and use of this kind of material, CO2 embedded in the plant material is bonded throughout the lifetime of the building.

Energy efficiency

Tuesday Afternoon Track B - S8
Apr 20, 14:15 - 15:05

OR-22

Energy efficiency of buildings in the context of sustainability

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Energy efficient buildings are the key components for the transition into a sustainable and low-carbon built environment, while offering people better living conditions. In order to increase the energy efficiency of buildings,

the European Commision has put in place a legislative framework to promote policies aimed at achieving a highly energy-efficient and decarbonised building stock, as well as establishing the basis for a more stable economic environment. The Commission also presented a renovation strategy to accelerate the energy renovation of buildings and encourage their deep renovation. For the ultimate goal of energy efficiency, i.e. the zero- or even plus-energy standard, the Commission encourages the development of innovative technologies and supporting processes for buildings. However, to achieve energy efficiency and all other aspects of sustainability, these solutions are not always fully optimized. There is also a lack of methodologies to provide comprehensive analyses of buildings, as envisioned by the sustainability concept. Moreover, despite advances in digitalization, automation and monitoring in the construction sector, there is still a large quality performance gap between planning and reality - not only due to construction processes, but also as a result of unforeseen and inappropriate user activities.

OR-23

Consumption and potential energy savings in the office building

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This research illustrates the concept of using dynamic simulation as an instrument for the assessment and analysis of the final energy performance for the new office building of the Municipality of Prishtina. The aim is to analyse the energy performance in this building by predicting energy consumption during the phase of further interventions. The same analysis were done also for other two cities such as Peja and Ferizaj.
In this study, the total energy consumption was examined for this building model according to the detailed design project through dynamic simulation calculated by ARCHICAD tool and add-in EcoDesigner Star. The results of this paper suggest that much better improvement can be achieved by intervening in building envelope than in high-cost equipment.

OR-24

Thermal bridge assessment in prefabricated ventilated façade systems with recycled aggregates

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Despite numerous national regulations, it has been shown that the traditional practice when insulating building envelope is insufficient if not enough attention is given to thermal bridges. Heat losses through thermal bridges are much higher than through the surrounding area. Because of that, the thermal bridges are accompanied by lower surface temperatures, resulting in the higher risk of water vapour condensation and the formation of mould, and ultimately building damage. Therefore, much attention should be given to the design of thermal bridges and ultimately, its construction. This paper deals with the impact of thermal bridges on the outer building envelope of the ventilated façade system of the first ECO-SANDWICH® house in Croatia. The house was built in Koprivnica as part of the Green Zone project and is designed according to the standards for passive houses, i.e. A+ energy class, using innovative, ventilated Eco-sandwich® façade panels, designed at the Faculty of Civil Engineering, University of Zagreb. Details of thermal bridges in this paper will be modelled as linear thermal bridges, according to the HRN EN ISO 10211 standard, and therefore the heat flow was modelled as two-dimensional. The numerical calculation was carried out by software specialised for the heat flow and thermal bridge calculation – Flixo. The output result, linear heat transfer coefficient (Ψ), which quantifies the impact of linear thermal bridges on the one-dimensional heat flow, will also be analysed by variation of parameters, such as thermal insulation thickness. Finally, the numerical results were compared with the results obtained by default values of linear thermal bridges according to the standard HRN EN ISO 14683 to show the error between the results obtained by the numerical calculation and the default values which are typically taken in the traditional calculation of heat losses in buildings.

Inspection, monitoring, assessment and repair

Tuesday Afternoon Track C - S9
Apr 20, 14:15 - 15:05

OR-25

Inspection and monitoring of bridges to support the management activities of critical infrastructure

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When we are responsible for rationalising the process of maintenance to provide safe and serviceable bridges one needs to look further to utilize state-of-the-art techniques to inspect, and monitor the condition of their infrastructure. In this paper, different techniques supporting this process will be briefly presented and case studies will be given. Principal inspection is one of the most essential and indispensable part of any bridge management system (BMS) to collect bridge condition data. It is very popular lately to find new ways to increase the level of digitalisation and automation in the current bridge condition survey procedures. Some insight in the undergoing research project to validate digitalisation possibilities for monitoring the bridge condition state using drones equipped with state-of-the-art sensors will be given. However, there are cases when the bridge condition has to be assessed with a more in-depth analysis, i.e. the reliability assessment of the structure. In such cases, bridge weigh-in-motion (B-WIM) technology can be used for the so called short-term

monitoring or soft load testing (SLT). This is a measurement of the response of a structure under the known axle loads in free-flow traffic. It can have a decisive impact in the optimal bridge reliability assessment since it enables to measure the most relevant structural performance parameters (influence lines, dynamic load amplification, …). The results imply that a less conservative method is available to assess the realistic structural safety of bridges and, consequently, more optimal rehabilitation measures can be selected. To minimise the occurrence of exceptional events, long-term monitoring tailored to each case study can be used. In this way pre-targeted performance indicators of the bridge are controlled. If coupling of B-WIM and SHM system is applied, additional traffic data can be collected and validation of structure's response in case of exceptional transport can be performed.

OR-26

Inspection, assessment and repair of fire damaged concrete structure

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Fire is a potential threat for any building and can seriously damage the structure. Structural response to fire is very complex and depends on used construction materials, type and geometrical characteristics of structural elements, duration and nature of fire, existing structural loads, structural and architectural details, etc. Proper design and successful repair of RC structure damaged in fire can only be provided if a detailed in-situ investigation, laboratory investigation and correct assessment of residual structural capacity is made. In December 2017, the basement of a building in Skopje was in fire. A part of the structure was in fire and the last three spans were completely burned. According to the damages recorded in situ, it was found out that fire caused severe damage to the reinforced concrete bearing structure. After the visual inspection, the residual concrete strength was defined by sclerometer and the results were compared with results obtained by the nonlinear transient heat transfer analysis of fire exposed elements. For the thermal analysis and for the nonlinear stress-strain analysis of the whole structure the program SAFIR was used and the results are presented in this paper. The results showed that during the fire action the strength and stiffness of structural elements were significantly reduced. Based on these results and the detailed in-situ investigation, an adequate repair of the damaged elements of the bearing structure was suggested and details are presented in this paper.

OR-27

Comprehensive permanent remote monitoring system of a multi-span highway bridge

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As part of the reconstruction of a multi-span viaduct on a Slovenian highway, a permanent remote monitoring system with over 200 sensors was established. Several parameters are monitored on different parts of the viaduct by means of temperature sensors, accelerometers, strain gauges, long-gauge deformation and Fibre Bragg Grating (FBG) sensors. In this way strains, frequencies and temperatures on external prestressed beam cables, carbon fibre rebars used for the flexural strengthening of a deck overhang, pier caps and prestressed beams are measured and stored into the on-site central data acquisition system. This paper presents architecture of the permanent bridge monitoring system and preliminary results of the measurements.

Innovations in materials and technologies

Tuesday Late Afternoon Track A - S10
Apr 20, 15:20 - 16:05

OR-28

Mode of operation of bio-based polymers for the control of fresh concrete properties

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With increasing industrialisation and efficiency increase of concrete casting, rheology control has become a relevant parameter for concrete. A functioning casting and hardening process does not only allow for more innovative processes but also ensures the durability and functionality of the concrete later at hardened state.
While today polycarboxylate based superplasticizers are well established and allow for effective and tailored yield stress control, their application in cementitious systems, in which the ongoing hydration causes variabilities, can create robustness challenges. Therefore, often additional rheology controlling admixtures are applied, which help increasing the robustness. Typically, polysaccharides are used of various origin. These polymers depending upon the source and processing can have multiple characteristics, and to date the published data on polysaccharides with and without supplementary superplasticizers is very limited.
With increasing need to develop greener technologies for construction, in this paper various plant-based sources of polysaccharides have been studied that can be obtained in Europe and Africa. Their interactions with cement and superplasticizers are studied regarding their influence on the rheology of cement-based systems. Their mode of operation is then explained considering their specific polymeric properties in the ionic environment of cement paste.

OR-29

Mechanical properties of concrete containing wood biomass ash

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Renewable energy, together with environmentally-friendly materials, gives us an insight into a sustainable future – one where reliance on fossil fuels and greenhouse gas emissions are minimised. The leading source of renewable energy in the EU are biomass fuelled power plants. Among different types of biomass, wood has the widest application while holding the majority share with 59% of all renewable energy sources. Nevertheless, combustion of 1 tonne of wood biomass generates approximately 3% of wood biomass ash (WBA), resulting in large amounts of waste. WBA management is an issue in need for prompt solutions, to avert further endangerment of the environment as well as disposal costs. Using WBA as partial cement replacement is considered to be a feasible application in cement composites. However, the fluctuating chemical composition of WBAs somewhat differs from coal fly ash, already acknowledged as a supplementary cementitious material. Due to the aforementioned difference and lack of standards and guidelines for WBAs application in cement composites, its wider application is still limited. Therefore, the main goal of this research was to quantify the acceptable amount of fly WBAs in concrete, while considering the chemical composition of different fly WBAs. Three WBAs utilized in this research were collected from different power plants located in Croatia, that exploit untreated wood chips as fuel while applying pulverised fuel combustion and grate firing as combustion technology. Six concrete mixtures were prepared with ash content of 15% and 20%. The impact of each WBA on concrete properties was analysed based on the determined compressive strength and modulus of elasticity. Differences between particular WBAs have been reflected on the properties of concrete mixtures. In general, it can be concluded that concrete mixtures with WBA display similar behavioural trend of decreased compressive strength and modulus of elasticity.

OR-30

Influence of waste glass addition on concrete properties

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In order to address environmental effects associated with cement manufacturing, there is a need to develop alternative binders to make concrete. Crushed waste glass accumulated at some extent has a negative environmental impact, moreover likewise there is a propensity of cement production manufactures toward using supplementary cementitious materials that result on less emissions in terms of the environmental pollution. In this paper it will be highlighted the key findings of milled/crushed waste glass as a substitution of cement content for concrete production. The study is tackled at two different levels. Firstly, the interaction of cement and milled waste glass will be established through fresh (consistency, flow test and setting times) and solid state (mortar bending and compression tests). These findings will lead on optimal substitution content of waste glass with respect to cement. At the second level a correlation between crushed waste glass and aggregate grading curves will be established through series of tests at fresh (slump test) and solid state (compression and bending tests). In the same time the chemical analysis of waste glass will be presented and interaction with cement will be discussed. This paper gives an overview of the current progress and recycling situation of waste glass and point out the direction for the proper use of waste glass as replacement of cement. The role of glass powder as replacement of cement provides considerable value-added utilization and significantly affects the output of greenhouse gases from cement industry. This paper presents the feasibility of the substitution of waste glass powder for cement to achieve economical and environmentally friendly construction material. These will not only help in the reuse of waste glass but also tents to create a greener environment.

Energy efficiency

Tuesday Late Afternoon Track
B - S11
Apr 20, 15:20 - 16:05

OR-31

The Impact of Building Zone Elements on Airtightness

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To achieve the goals set by the European Union (EU) in terms of energy savings and decrease of the greenhouse gas emissions, the member states of the EU obliged that they would increase the number of the Nearly Zero-Energy Buildings (NZEB). That increase has to be accomplished not only by building new NZEBs but also by deep energy renovations of old ones. One of the criteria to fulfil NZEB demands is to ensure the airtightness of the building, which is usually tested by an air pressurisation test. As there will be a great number of buildings which must undergo the testing in the near future, it is important to find a way to speed up the testing for the multizone buildings. This paper presents research based on the results of building zone airtightness estimations based on a fan pressurisation test by the so-called Blower Door system. It is a part of research whose goal is to develop a predictive model of the air-change-rate for a multizone building based on randomly tested zones. The paper describes a connection between the airtightness of tested building zones and elements which make up these zones. This research is crucial as a starting point for the development of the predictive model in order to define the parameters

that affect these measurements. Statistical analysis was performed not only for the analysed results but also for an exploration of the connection between the zone elements and the zone's airtightness as well. The paper presents a hypothesis based on the abovementioned research and proposes further research for the future development of the model.

OR-32

Street furniture design as a means to mitigate urban heat island phenomenon: A case study

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Climate change combined with urban heat island effect makes cities particularly vulnerable to summer heat. Higher overall summer temperatures and especially periods of intense heatwaves are a major health issue for populations living in dense urban environments. Risks are even higher for low-income neighborhoods since they tend to have higher population density and fewer green areas which act as a cool refuge during a crisis. Missing Tree explores an alternative strategy for urban heat island mitigation in dense urban areas where tree plantation is not possible. In many cases, cities are in fact mineral deserts where rainwater is evacuated as quickly as possible through surface runoff and sewerage. Missing Tree is part of an effort to locally restore the water cycle: precipitation, infiltration, evaporation.

The prototype presented here is a tree for urban public spaces where access to open ground is impossible. It is made of a new permeable humidity retaining mineral building material. Future designs could take shape of a meadow, a bush or even another form beyond reference to plants. Missing Tree is the first in a collection of objects for urban public space which aims to make the city better suited for the changing climate.

The design strategy uses new capabilities of computational design and fabrication to combine social and environmental issues. The resulting objects provide possibilities for non-directive use in urban public space and are at the same time part of the cooling infrastructure to mitigate the urban heat island effect.

Permeable humidity-retaining mineral material stores rainwater and prevents overheating through evaporative cooling. The material is under development and has been tested in laboratory conditions.

Design and material science combined provide an innovative approach to urban rainwater use for climate change mitigation in dense urban areas.

OR-33

Effects of energy renovation measures implemented on a residential building

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To achieve ambitious energy and environmental goals set by the European Commission, also existing buildings will have to meet the energy efficiency requirements. The building stock represents a huge potential for renovation in terms of energy use and environmental impacts, as well as the quality of living. Interventions in the buildings in terms of measures for more efficient use of energy practically always bring a positive result, but they need to be well planned for optimal effect. The calculated energy use for a building is an approximation of the real value, which depends on many parameters and the quality of the input data. The article presents a comparison between the measured energy use for heating with the calculated values for an old residential building. The comparison was made in the light of gradually implemented energy efficiency measures. Two software packages were used for the analysis, PHPP 2007 on monthly and annually calculation basis and KI Energija 2017 on monthly calculation basis. For each phase, simulations were prepared for diverse average indoor air temperatures, and the results were compared with the measured values. The study proved that, despite methodological differences, all the calculation methods involved provide a good basis for defining energy use for each energy efficiency measure. The analysis showed that the annual calculation method is accurate enough to determine the energy use of energy efficient buildings on an annual basis. It was also found that in the case of non-renovated building, the simulation results match the measured values when lower average indoor air temperatures are used than expected. Therefore, to calculate the energy savings for heating during an energy renovation of building, it is necessary to know the average indoor air temperature before its renovation. Otherwise incorrect conclusions can be drawn about reduction of energy use through renovation measures.

Inspection, monitoring, assessment and repair

Tuesday Late Afternoon Track C - S12

Apr 20, 15:20 - 16:05

OR-34

Corrosion-cracking parameter in the concrete structure and impact in reinforced steel bars

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Concrete structures are under the different environmental conditions, which phenomena will lead to the damages of structure in the time factor. The bridge structures are more attacked, focused on corrosion of steel bars, and with damages of structure elements. Corrosion is caused by many factors of the external environment which, through the protective layer of concrete, reaches the reinforced steel bars in the process caused by the degradation of the concrete in general. The presence of permanent humidity is the permanent factor that involves in the process many other factors from the aggressively of environment substances: chlorine, oxygen, carbon dioxide, sulfates, during the penetration process in concrete. The

case study analyzing in this paper is a bridge structure, located in village Drelaj, the region of Rugova, mountains in Kosova. The bridge is at an altitude above 2000m and is under the constant influence of extreme temperature conditions. The methods to be applied in this case are analytical and experimental methods. The analytical method is based on measurements and calculate the depth of corrosion according to ASTM code and calculate the percentage of corrosion according to ACI code. The experimental laboratory method we will determine the corrosion rate with the Corrosion meter instrument. In the end, we will make a comparison between the results achieved, and the proposal for repairing, to increase the bearing capacity.

OR-35

Monitoring of steel corrosion in concrete exposed to marine environment

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Steel in concrete exposed to marine environment is susceptible to chloride induced corrosion, but certain details related to interchange of water and oxygen and consequent macro-cell coupling are poorly known. In order to understand the influence of periodic wetting and drying, a set of reinforced concrete columns fully equipped with various types of probes were exposed at sea level and continuously monitored. 16 steel electrode and 5 electrical resistance (ER) sensors were equally spaced along the column height. The steel electrodes, which are configured as coupled multi-electrode arrays (CMEA), and the ER sensors were both connected to data loggers and measurement data are transmitted wirelessly to the cloud. Water temperature and sea level are also monitored.
The effects of changing water level on corrosion rates at different column heights will be presented. The influence of the different exposure zones, as the deep water exposure, the tidal zone, the splash zone and the dry zone, will receive particular consideration. The obtained results will identify critical areas with higher or lower corrosion rates, which might influence future design decisions of partially submerged reinforced concrete structures.

OR-36

Migratory corrosion inhibitors technology for improving durability of europe's bridges infrastructures

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Bridges are of vital importance to the European infrastructure network. Due to its significance in the political economy, the demand for sustainable is emphasized, which means very advanced, economical, environmentally friendly, and long-lasting constructions. Now, the European market is dominated by concrete bridges. A survey on condition assessment of European bridges showed that 1/3 of the bridges has symptoms of deterioration, with carbonation and/or chloride induced steel corrosion as main degradation mechanisms. Accordingly, significant resources are put in the maintenance of such bridges often at higher costs and prior then planned.
By using migration inhibition technology in severely corrosive environments, structures can have a stronger resistance to corrosion and therefore longer durability. Increased durability means fewer repairs, enhanced structural integrity and a longer service life, all leading to greater sustainability. This paper presents a review of the present status of migratory corrosion inhibitors technology that is to be used regarding improving durability design of new and existing structures. The focus is placed on the European scenario and on the most widespread deterioration mechanisms: steel corrosion induced by chlorides (very frequent in marine environments or in cold regions where deicing salts are applied) or by carbonation.
This paper includes some analyses of concrete bridges; service life assessment, including comments on life-cycle costs; and concludes with discussion of design options that have been used or have become available recently that might be considered to achieve a service life of 120 years for major concrete bridges.

Digitalization and automation

Wednesday Morning Track A - S13

Apr 21, 10:10 - 11:00

OR-37

Implementing BIM in Slovenian Public Sector

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In Slovenia, BIM has been first used among designers. Consultants and engineers at DRI were introduced to BIM in recent years by trainings and additional education and they soon recognized the advantages that this technology can offer. In 2015 siBIM, BIM Association Slovenia, was founded, uniting experts from differed fields of engineering and architecture in order to further encourage the use of BIM.
Executives of DRI, a state owned company, which mainly deals with managing large public infrastructure projects in the country, encouraged the initiative and first presented its advantages to one of the major public clients DARS, the Motorway Company of Slovenia. DARS saw possible benefits and, as the first public client, requested BIM in his latest large project: the construction of the second tube of the Karavanke tunnel at the Slovenian - Austrian border. Recently, some other public projects have been designed using BIM for both railways and housing projects.
In 2016 Slovenia became a member of EU BIM Task Group. The aim of the group is to bring together national efforts into a common and aligned European approach to develop a world-class digital construction sector.
siBIM is organizing annual conferences and has reached out to several Ministries in the country to present the advantages of BIM for the public sector. Ministry of Economic Development and Technology appointed siBIM to prepare "Slovenia BIM Roadmap" with the intention to be adopted by the Government.

The establishment of the Technical Committee for BIM within SIST, Slovenian Institute for Standardization will additionally increase the development of BIM in the country. We are ahead of another important step forward by establishing buildingSmart Chapter Slovenia.

OR-38

Designing generatively to achieve an efficient and optimised solution

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Recent developments in the field of artificial intelligence and related areas have opened up new possibilities for computers to generate solutions independently. One such approach is generative design. Generative design is proving to be an efficient alternative design approach to the traditional processes. In this paper we present the framework for generative design, which is characterised by three main features: computational model, generator and design evaluation. This framework was applied to the practical example of the search for an efficient passive shading system with complex geometry. Here we used BIM models from Revit and Dynamo environment to build a computational model. For the generation and evaluation of the design alternatives Project Refinery was used together with Python. We have learned that this approach can be beneficial to us by automating the search for design solutions, creating complex designs we wouldn't think of and generating more design options from which we can find the efficient design more quickly. The same approach can be applied to any real-world design problem which we can translate to the computational model.

OR-39

Enriching building information model with environmental quality monitoring for healthy living

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As we spend more than 90% of our time inside buildings, indoor environmental quality is a major concern for healthy living. Recent studies show that almost 80% of people in European countries and the United States suffer from SBS (Sick Building Syndrome), which affects physical health, productivity and psychological well-being. In this context, environmental quality monitoring provides stakeholders with crucial information about indoor living conditions, thus facilitating building management along its lifecycle, from design, construction and commissioning to usage, maintenance and end-of-life. However, currently available modelling tools for building management remain limited to static models and lack integration capacities to efficiently exploit environmental quality monitoring data. In order to overcome these limitations, we designed and implemented a generic software architecture that relies on accessible Building Information Model (BIM) attributes to add a dynamic layer that integrates environmental quality data coming from deployed sensors. Merging sensor data with BIM allows creation of a digital twin for the monitored building where live information about environmental quality enables evaluation through numerical simulation. Our solution allows accessing and displaying live sensor data, thus providing advanced functionality to the end-user and other systems in the building. In order to preserve genericity and separation of concerns, our solution stores sensor data in a separate database available through an application programming interface (API), which decouples BIM models from sensor data. Our proof-of-concept experiments were conducted with a cultural heritage building located in Bled, Slovenia. We demonstrated that it is possible to display live information regarding environmental quality (temperature, relative humidity, CO2, particle matter, light) using Revit as an example, thus enabling end-users to follow the conditions of their living environment and take appropriate measures to improve its quality.

Material – environment interaction

Wednesday Morning Track B - S14
Apr 21, 10:10 - 11:00

OR-40

The importance of understanding microstructure of alternative binders to predict their durability

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It is now more obvious than ever that the only option for the development of the built environment is a sustainable and environmentally responsible one. In the field of building materials, especially in concrete technology, there are many studies that deal with alternative raw materials, such as by-products, recycled materials or natural resources that are not fully exploited. However, with the alternative materials, alternative durability challenges may also arise. More so, some of the known durability challenges may re-emerge in alternative forms.

Alternative materials have different chemical and physical properties compared to a classical system. Different reaction products, different pore structure, electrical resistivity or tortuosity of the pores can lead to different behaviour of the materials and their degradation mechanisms. To predict and control the durability of alternative materials in the environment, a complete understanding of their microstructure is of utmost importance.

In the present work, some examples of developed alternative binders based on local materials are presented. Among others, binders based on high cement replacement,

binders based on calcium aluminate and alkali-activated binders are discussed. Among the degradation mechanisms, chloride penetration, corrosion and carbonation and their specific mechanisms with alternative binders are addressed.

OR-41

Measurement of the chloride resistance of Environmentally friendly and Durable conCrete

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The increasing demand for concrete and thereby Portland cement, creates the need for novel low-clinker Portland composite cements. Concretes prepared with such novel composite cements need to show similar or even improved durability compared to concrete prepared with commonly used Portland composite cements. This study represents a part of the EnDurCrete project that focuses on the durability of concrete produced with novel low-clinker cements, containing high-value industrial by-products. More specifically, we investigated the chloride ingress resistance of such concrete. Concrete cylinders were submitted to chloride ingress by bulk diffusion. The chloride ingress resistance was investigated on concrete samples by µXRF scanning and chloride titration. In addition, the chloride binding capacity of these novel binders was investigated on paste samples by determining chloride binding isotherms for both binders. In the next step of the project, these experimental results will be matched with an advanced model, which is being developed within the project. By combining modelling with experimental verification, we aim to reach a better understanding of the fundamental chloride ingress mechanisms acting on novel types of concrete. The overall goal of the work is to produce a concrete with lower cost, lower environmental footprint and with verified similar or improved durability.

OR-42

Sulfate resistance of cement with different volumes of fly ash

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Sulfate attack is complex severe set of chemical and physical processes that have great influence on concrete durability. Sulfate resistance of concrete should be obtained by requirements for low-permeability, use of sulfate resistance cement and proper production. In this paper an experimental research is presented on the possibility of using fly ash as a partial replacement of cement clinker and its influence on the sulfate resistance of cement. For that purpose, four samples of fly ash from the TPP Bitola were taken in the time period of two weeks. All cement components including fly ash were completely tested from the aspect of chemical composition and physical properties. Two samples of fly ash which showed the biggest difference in their fineness were chosen for further investigations and preparation of cements. Laboratory cements were prepared by varying the quantity of fly ash as replacement of clinker, from 0% to 50%. For all laboratory produced cements complete chemical analysis and determination of the physical and mechanical properties have been carried out. The method of Koch & Steinegger and the recommendations of the Technical Committee of Cement in CEN/TR 15697 were used for determination of sulfate resistance of the laboratory cements. According to this method, small specimens (prisms with dimensions 10/10/60 mm) were prepared and then cured in deionized water and aggressive solution – 4,4% Na2SO4. The corrosion coefficient calculated on the basis of flexural strength of the specimens tested after 56 days in aggressive solution was used as indicator of sulfate resistance of the cements. On the basis of the test results, it is determined that the fly ash and cements fulfill the quality criteria defined in the standards. It is also concluded that the cements with 30% fly ash show the best results from the aspect of sulfate resistance.

Construction, maintenance and modelling

Wednesday Morning Track C - S15

Apr 21, 10:10 - 11:00

OR-43

Predictive maintenance planning for transport infrastructure

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Infrastructure maintenance is a complex task due to the number of factors, e.g. safety and availability requirements, ageing of the existing assets, increased traffic intensity and budget constraints. With the shift from manual to computerized solutions, many transport agencies are storing and managing the immense amount of data related to assets' properties and their operational performance. Yet, the maintenance planning of these assets is still mostly driven by available budgets, planned schedules, experts' intuition, and sudden failures. Road and railway agencies are lacking automated solutions or decision support models that could make the use of available data and could assist in decision-making processes.

In this paper, different approaches for development of decision support models for optimization of maintenance planning will be presented. A typical predictive maintenance modelling framework and its key components are going to be discussed. Finally, the application of machine

learning models on large number of assets along the transport infrastructure network will be illustrated.

OR-44

Ductility of Hybrid FRP – Steel Reinforced Concrete Sections

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Reinforced concrete is a widely used structural material. Usually, steel is the material used for reinforcing elements. Most important problem with using steel is the fact that it is susceptible to corrosion, which significantly affects durability of a structure. Fiber reinforced polymer (FRP) materials can be used instead of steel to avoid corrosion. FRP can either be used for repair of existing, or design of new structures. Different materials can be used to form FRP reinforcement, each having their own modulus of elasticity and strength, but all of them behaving elastically until failure. Usually, stiffness of steel is greater than stiffness of FRP bars, making FRP reinforced elements more sensitive to deflections. Hybrid FRP – steel reinforced members mitigate insufficiencies of both elements reinforced only with steel and elements reinforced only with FRP. Behaviour of hybrid reinforced members depends on not only the amount of each type of reinforcement, but also on its distribution inside a section. Since ductility of sections is important for overall structural response, a more detailed analysis of ductility is given in this paper. Different concrete sections with the same bending moment capacity are analyzed. Only rectangular sections under bending moment are considered in this paper. Concrete class, width and height are all kept the same, while the rebar material, amount and layout are varied. Bending moment – curvature diagrams are obtained and compared with each other, as well as section stiffnesses.

OR-45

Flexible polymer connections for clt structures

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This paper explores the possibility of using flexible polymer adhesives to dissipate energy in CLT buildings during earthquakes. In the first series of tests, pull-off tests of various polyurethane (PUR) adhesives were performed. The connection was tested in pull-pull configuration using monotonic, tension-only loading. The tests have shown that the adhesive can resist large deformations already in tension loading and with small thicknesses of the bond-line. Based on the pull-off test results, one adhesive has been selected for further testing. Monotonic lap-shear tests were performed with the selected adhesive and thick bond-line (3 and 6 mm). The results show, that the standard method for lap-shear testing (EN 205) needs to be adapted for thick glue-line. It was found that the strength of 3 mm glue-line is higher than 6 mm one, which is in agreement with adhesion theory. The flexible PUR adhesives could potentially be used in CLT structures for anchoring the CLT wall with "flexible" glued-in rods or as a "flexible" vertical shear connection between the CLT walls. Such systems have a potential to dissipate energy in seismic areas.

Digitalization and automation

Wednesday Before Noon Track A - S16
Apr 21, 11:15 - 12:00

OR-46

Bim application in civil engineering projects

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BIM, abbreviation from "Building Information Modeling" is a relatively new concept in the technical disciplines. Scientists, engineers and designers consider this technology as future in all stages of design. In traditional design, there are two-dimensional elements, while BIM also implies a third dimension. However, the BIM model of an object is not just a 3D model, it is also a model that contains numerous kinds of data and information that can be used and manipulated throughout the whole life cycle. This paper gives an overview of BIM technology and modeling based on captured data. The obtained point cloud, as input data is obtained by laser scanning. Two case studies are presented - creating a 3D smart home model and 12 km long rail.

OR-47

Education for zero energy buildings using Building Information Modelling

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The construction industry across Europe is facing major challenges in achieving energy efficiency targets, in particular for Near Zero Energy Building (NZEB), but they are also experiencing a digital revolution, with Building Information Modelling (BIM). The Fit-to-NZEB, Net-UBIEP (Horizon 2020) and BIMzeED (Erasmus+) projects intend to improve the human-capital basis of the construction sector, which is identified as a strategic initiative by the European Commission, acting on Higher Education Institutions (HEIs) and Vocational Education and Training (VET) systems in Europe. These projects support the construction industry, through education and training to upskill on technical innovation and digitalization. Not only is digitalisation trainings an important focus for the progression of the construction sector, but providing a low carbon efficient economy requires the integration of BIM with nZEB design and development approaches. At EU level, the challenge remains to introduce relevant standardised environmental and energy efficient learning topics into mainstream training and degree courses at HEIs & VETs. This paper analyses the current situation in the Ar-

chitecture, Engineering and Construction (AEC) industry in several EU countries and provides a possible solution for the abovementioned problems in the field of NZEBs and BIM.
The analysis of current formal and informal educational programs in the AEC industry revealed that topics related to the DER and NZEBs are not adequately covered, or not covered at all, resulting with a lack of qualified workers and professionals. Another major problem detected in the conventional project delivering is an absence of integrated or interdisciplinary approach between all the stakeholders.
This paper will show how the competences of construction stakeholders in the field of NZEBs and BIM can be increased.

OR-48

Characterization of the reaction degree of slag in a cement by neural networks based electron microscopy image analysis

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Ground granulated blast furnace slag is often used as a supplementary cementitious material in cement to improve the durability of the cement and reduce CO2 emissions. The performance of the slag containing cement depends on the degree of reaction of the slag, which makes measurement of the reaction degree essential. Commonly used methods are XRD, selective dissolution and electron microscopy image analysis. RILEM round robin results have shown that XRD-PONKCS required further protocol development and selective dissolution tended to underestimate the degree of reaction. Electron microscopy seemed to give more consistent results, however, image analysis using BSE images + EDX mappings is time consuming and resolution dependent. Developing an image analysis algorithm that correctly segments the electron microscopy images can take a long time, involving many cycles of trial and error and is user dependent. In our study, we compare classical "manual" image analysis to artificial intelligence assisted image analysis using artificial neural networks for determining the reaction degree of slag in cement. Artificial neural networks are a type of machine learning model that will independently attempt to find the optimal way to segment an image based on a limited number of example segmentations (training cases). In addition to using color information to segment, these networks can also recognize phases based on shapes and textures. Therefore, they have a large potential to enhance image analysis. We use a real hydrated cement containing GGBFS and show that the reaction degree of GGBFS obtained by a neural networks based model is similar to "manual" image analysis and XRD PONCKS. Furthermore, the neural network model proved to require less development effort and contains less systematic errors than the "manual" image analysis making it a promising technique to use in the future.

Material – environment interaction

Wednesday Before Noon Track B - S17
Apr 21, 11:15 - 12:00

OR-49

Comparative study of selected properties of three binders: blended portland cement, calcium sulfoaluminate cement and alkali activated material based concrete

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The dependency on cement as the main binder in the manufacturing of concrete has increased the demand for cement. Though it is vital for construction, it has a significant carbon footprint as during its production, high energy is consumed, and greenhouse gases are emitted. According to recent studies, the cement industry currently contributes to approximately 10% of total global CO2 emissions. To reduce the adverse effects, research has been ongoing following the principles of sustainability, to produce eco-friendlier alternative binders for the construction. In this experimental work, a comparative study was conducted on concrete prepared with calcium aluminate cement (CSA), Alkali-Activated Binder (AAM) and a reference blended Portland cement (PC). To evaluate the binders for potential utilisation, the compressive strength, capillary absorption, chloride diffusion and drying shrinkage were determined. The results indicated that CSA, though had higher chloride diffusion than PC on 28 days, this difference reduced on 56 days. At the same time, the difference between chloride diffusion of AAM and PC was exponential. The capillary absorption results indicated that both CSA and AAM achieved higher capillary absorption than PC. The drying shrinkage over time of CSA and PC were almost identical, whereas for AAM the shrinkage was much higher than PC and CSA at all tested ages of concrete. It was observed from the compressive strength that CSA achieved higher early age strength and similar 28-days strength as PC while the AAM showed significant difference at different ages. Based on the results obtained, it is pointed out that, if alternative binders are to be used in concrete structures, their different properties compared to PC should be considered during preliminary design of concrete in structures.

OR-50

Sulfate resistance of concrete after two years exposure to aggressive solutions

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SUMMARY: The sulfate resistance of four types of concrete immersed in 5% Na2SO4 or 5%MgSO4 solutions for period of 24 months was investigated. Two water to cement ratios were varied (0.38 and 0.55) and two types of common cement were used: portland cement (CEM I

42.5R) and blastfurnace cement (CEM III 32.5N LH/SR). Control specimens were cured in lime-saturated water. Sulfate resistance was monitoring through change in compressive strength and volume change. Thermogravimetric analysis and differential scanning calorimetry (TGA–DSC) were used as an additional analysis. It is concluded that both methods (change in compressive strength and length change) show results that lead to the similar assessment of sulfate resistance. The experimental results of chosen methods showed that the effect of w/c ratio was more pronounced for the portland cement, while the blastfurnace cement was less affected by an increase in the w/c ratio. Concrete will achieve satisfactory sulfate resistance after immersion in sulfate solutions for 24 months if appropriate type of cement or water to cement ratio is chosen.

OR-51

Effect of Chemical Admixtures on Corrosion Behaviour of Structural Steel in Mortar: Comparison between Standardized and Alternative Method

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Nowadays, corrosion of steel rebars is the most destructive durability issue in RCC structure. There are number of reasons behind this issue including chloride ingress and carbonation. In this study, the effect of two different type of admixtures (set retarder and water repellent) on corrosion resistance of steel in mortar system was investigated by method standardized in EN 480-14. In order to know the efficiency of standard procedure, another set of specimens were casted and assessed by an alternative corrosion detection method. All the specimens were exposed to 3.5% NaCl and saturated Ca (OH)2 solution and the corrosion activity monitored regularly. In standard method, corrosion activity was evaluated by measuring the maximum current density values during potentiostatic polarization. After detection of the corrosion, specimens were opened and checked to confirm the corrosion by visual observation. In the alternative method, corrosion was monitored for a specific period by linear polarization method.

Construction, maintenance and modelling

Wednesday Before Noon Track C - S18

Apr 21, 11:15 - 12:00

OR-52

Fibre Reinforcement - the Key to Sustainable Reinforced Concrete Structures

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One of the main reasons for strengthening, repair or even demolishing of concrete structures is the appearance of large deflections or cracks developed in the service life of the structures, caused by many different reasons. On the other hand, sustainability of concrete structures can be achieved if we avoid these actions by design of more durable structures. The addition of fibres to concrete is well known measure that can help in achieving this goal, proven by now on many short term test. Since there is a scarcity of long-term tests dealing with fibre reinforced concrete, to find out the influence of different types of fibre reinforcement on the long-term deflections and long-term cracks of concrete structures, an experiment was carried out at the Faculty of Civil Engineering–Skopje. The experiment consists of 12 full scale reinforced concrete beams, all manufactured with concrete class C30/37, but reinforced with different types (steel, macro and micro polypropylene fibres and their combination) and amount of fibres (0, 0.38%, 0.39% and 0.76% from the volume) and additional longitudinal and transverse reinforcement. The results from the long-term tests showed up that even small amount of added fibre reinforcement have big influence on both deflections and cracks, thus ensuring more durable structures and reducing the costs for their possible repair or strengthening in future.

OR-53

Experimental and numerical investigation of restrained shrinkage of concrete

Lucija Hanžič[1], Jurij Karlovšek[2], Tomaž Hozjan[3], Sabina Huč[4], Zhongyu Xu[2], Igor Planinc[3], Johnny Ho[5]
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To promote the understanding of shrinkage related behaviour of concrete used for tunnel linings the experimental and theoretical investigation including numerical and analytical approach was performed on ring-shaped specimens. Overall one analytical (an.) and two numerical models, namely (i) and (ii) were also developed. Models (an.) and (i) considered the restraining steel ring to be rigid, thus not exhibiting any deformation. Numerical model (ii) considered the steel ring to be deformable. The experimental set-up consisted of a large concrete ring with an inner diameter of 120 cm, an outer diameter of 160 cm and 20 cm in height. The restraining steel ring was 5.5 cm thick. Two concrete rings were made, namely R1 with a low compressive strength of ˜26 MPa and the other, R2, with medium compressive strength of ˜40 MPa. The strain was measured in the hoop direction on the inner circumference of the steel ring and on the outer circumference of the concrete ring. Concrete rings were subjected to circumferential drying. Numerical model (ii) predicted critical time to the formation of the first crack to be between 13 and

14 days. The experimentally determined critical time is found to be 11 to 13 days with cracks gradually opening over several days. This was indicated by changes in measured concrete and steel strain. Modelled concrete strain just before cracking was between -20 and 30 × 10 6 m m 1 however, measured concrete strain was ˜150 × 10-6 m m-1. Modelled steel strain was between -30 and -40 × 10-6 m m-1 while measured steel strain was between -10 and 20 × 10-6 m m-1. These discrepancies, in particular the positive steel strain obtained in experiments, require further investigation and improvements of the experimental set-up.

OR-54

Seismic Strengthening of Stone Masonry Structures – State of the Art

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In Croatia, a great amount of buildings are built in masonry. The majority of them were built before the development of seismic codes and a lot of them are vernacular, unreinforced structures. As a result, many of these buildings need to be evaluated and, if needed, strengthened. Today, codes and guidelines for the evaluation and retrofitting of existing masonry structures do exist but are not very comprehensive and require a lot of engineering subjective judgement to implement. Furthermore, the problem lies in the complexity of implementing retrofitting methods since most of the masonry buildings are in use (private or public) during the strengthening. Besides that, a great number of buildings in Croatia (i.e. City of Dubrovnik) and around the world built in stone masonry have a great heritage value so the requirements made by conservators play a part in the methods used as well. An overview of the most commonly used methods of seismic analysis and strengthening are presented in this paper. The main objective of this paper is to comprehend, gather and compare different state-of-the-art principles of seismic retrofitting of structures focusing on stone masonry. Different approaches are analysed and compared in order to get closer to a unified method of evaluation and strengthening of existing structures.

Digitalization and automation

Wednesday Afternoon Track A - S19

Apr 21, 13:00 - 14:00

OR-55

Novel Cementitious Materials for Extrusion-based 3D Printing

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3D printing (or 'additive manufacturing' (AM) systems used to manufacture cementitious structures, either in-situ or off site, utilise specialist formulations. This paper describes a new cementitious formulation which can be extruded from a syringe device without the requirement for the addition of an accelerator at the nozzle. This approach brings advantages in that the system required is smaller, lighter, consumes less power and is suitable for mounting on robots which are not reliant on external power or material supplies. Applications of this smaller scale system include concrete crack repair in hard to access areas and printing of specialist conductive formulations which can be used for sensing. Cementitious pastes were successfully printed using a miniature deposition device which could be carried by a small robotic printing agent. Appropriate workability and buildability following deposition was achieved through the use of cellulose gum additions to the mix formulation. Analysis and characterisation tests carried out on fresh mixes enabled comparison of a 1:1 mix of aluminium lactate and diethanolamine with the commercially available accelerator Master X-seed, and mixes with no accelerating admixture added. When compared to results featuring no accelerating agent, tests demonstrated that Master X-seed was the more effective accelerator, promoting early compressive and flexural strength development, but neither accelerator made a constructive contribution to rheological properties over a two-hour period. X-seed was the more effective, but rheology results suggest the difference occurs logistically too soon for a miniaturised deposition system. The retardation effect of cellulose gum and the potential role of in-situ and off-site miniaturised AM methods are evaluated.

OR-56

Temperature pre-treatment of gypsum for powder based 3D printing technology

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In recent years many researchers have been involved in studies in the field of pre-treatment of various raw materials. Temperature treatment of materials results in several advantages, which have been already recognised and successfully applied in various fields of applications. Where at the same time, the practices has been adopted also in the field of 3D printing. Enhanced strength and stiffness, assuring desirable performance criteria of the 3D printed models, reflect the most important characteristics. 3D printing binder jetting technology is based on the application of liquid binders onto powdered material, where gypsum powders have been commercially used as a base raw material. As natural raw materials can be replaced by other materials, such as recycled industrial by products, the aim of this research work was to evaluate the potential usage of three synthetic gypsum powders from different industrial processes for 3D printing. The investigation covered (a) mineralogical and microstructural characteristics of gypsums from different origin and (b) the effect of pre-treatment of gypsum powders at different temperatures (up to 500 °C). On the basis of the results, the most promising temperature regime for each different waste gypsum powder treatment, reflecting in the most

optimal setting time, was defined. Synthetic gypsums were characterized by X-ray diffraction (QXRD), scanning electron microscopy (SEM) and differential thermal analysis (TG/DTA). The results showed that all three synthetic gypsums (calcium sulfate dihydrate, CaSO4 2H2O) thermally degrade into calcium sulfate anhydrite (CaSO4) via an intermediate calcium sulfate hemihydrate (CaSO4 ½H2O, bassanite) phase. Microstructural and mineralogical differences were observed when temperature treated gypsums from different origins were compared. The detailed knowledge of gypsum powder properties at different temperature regime is important parameter for the assurance of 3D printing key parameters such as flowability, roughness and wettability, especially for determination of saturation levels and setting time. After all, these parameters define final mechanical properties of 3D printed structures.

OR-57

Development of sustainable lightweight 3D printing mixtures for 3D printing

Pawel Sikora[1], Karla Cuevas Villalobos[1], Jarosław Strzałkowski[2], Dietmar Stephan[1]

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Additive manufacturing of cementitious composites enables the optimization of the wall systems which cannot be achieved by using formworks. Through, optimization of the wall structure and thickness it is possible to improve their thermal efficiency, thus reduce the energy loss during heating and cooling seasons. However, to achieve this goal there is a strong need to balance between cavities and 3D printed material as well as decide on proper structure of wall system. In addition, there is a necessity to develop a 3D printable mixture composition with low thermal conductivity without disturbing mechanical properties. The purpose of this work is to develop sustainable lightweight concrete mixture to produce 3D printed wall systems. To achieve this goal waste glass aggregates as well as expanded microspheres were incorporated to the mixture. Fresh and hardened properties of printable mixtures were evaluated. Incorporation of waste glass aggregate and expanded microspheres allowed to reduce the density of the mixture as well as decrease its thermal conductivity. Wall configurations with different fillers were designed to evaluate thermal transmittances (U-values) of the printed walls. The cavities between printed elements were filled with air, ultra-lightweight foamed concrete or polyurethane foam. Through simulation studies, the most thermally-effective wall system was developed in order to meet the U-values regulated by EU towards applying them as a building envelopes.

OR-58

3D multi scale imaging in additive manufacturing

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In recent years, many new characterization techniques have been introduced and improved in material science. A wide and diverse range of methodologies is now available in 2D and 3D scale imaging, combining the power and advantages of different imaging systems, e.g., light, electron, ion, X ray [1,2]. All of these methods are being implemented as correlative methods, providing valuable information about the examined samples. By applying multiple workflows in additive manufacturing, the identification of impurities or dislocations can be made, as well as understanding the process that led to the errors. Correlative microscopy can also be implemented in the detection of the deformation and potential structural failure of the fabricated elements. This study aims to investigate experimentally (a) the effect of the "gypsum like" powder material characteristics on the elements fabricated via binder jetting additive manufacturing by electron, ion and X ray microscopy (XRM) techniques, (b) to observe internal processes such as cracks initiation and propagation down to the micro scale by the in situ use of the 3D XRM observation chamber under compressive loading and (c) to evaluate the possible combinations of multiple techniques, going from the micro to nano scale. Understanding the characteristics of printed elements by binder jetting is crucial, especially for improving accuracy, material compatibility and the mechanical properties. With unique multiple methods such characteristics can be better understood, nevertheless it is well known that none of them can offer a read out of all characteristics simultaneously, and a combined effort should be implemented.

[1] https://www.zeiss.com/microscopy/int/products/correlative-microscopy.html

[2] Toshio Ando et al 2018 J. Phys. D: Appl. Phys. 51 443001

Material – environment interaction

Wednesday Afternoon Track B - S20

Apr 21, 13:00 - 14:00

OR-59

Study on mechanical and durability properties of concrete with RTPF after high temperature exposure

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This paper presents the results of an experimental study conducted to evaluate the effect of recycled tyre polymer fibres (RTPF) on the mechanical and durability properties of concrete after high temperature exposure as an alternative to polypropylene fibres (PPF) for spalling mitigation. For this purpose, three different concrete mixes were tested: conventional concrete without

fibres and two mixes with 2 kg/m3 of RTPF and PPF respectively. After one year of curing, the specimens were tested under ambient conditions and after exposure to a predefined elevated temperature of up to 500°C with respect to compressive strength, modulus of elasticity, UPV and water absorption. The results obtained in this study lead to the important conclusion that the addition of RTPFs in an amount of 2 kg/m3 can be used as a substitute for PPF to prevent explosive spalling in heated concrete, but without further degradation of the mechanical and durability properties that may be caused by their melting.

OR-60

Effect of Binder Composition on Carbonation Resistance of Sustainable Concrete Formulations

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Sustainable concrete formulations typically have low clinker content and a high portion of supplementary cementitious materials (SCM), so that their carbonation resistance may be low. In order to investigate microstructure and carbonation resistance of blended binders systematically, in the presented test series the portion of OPC was varied from 100% to 60 % and specific SCM were added: 2 different limestone powders (LSP) and finely ground granulated blast furnace slag (GGBFS). Specimen were exposed to both natural and accelerated carbonation exposure with 0,04% and 2% of CO2, respectively. Porous microstructure as dominant factor governing the durability behavior was investigated by Mercury intrusion porosimetry (MIP) and low nitrogen adsorption porosimetry (BET), while the mechanical properties were assessed by compressive strength assessment up to 182 days. Gas transport and water uptake were evaluated by air permeability measurements and dynamic vapour sorption (DVS) tests. Compressive strength assessment indicate significantly higher strength increase at early age (from 1st through 28th day) of blended formulations compared to reference OPC mortars, highlighting the positive influence of combined contribution of latent-hydraulic reaction and LSs „filler-effect“ on early strength development. It is shown how different binder compositions influence capillary pore size distribution and subsequently fluid (gas and water) transport properties. Consequences for the carbonation resistance of blended mortars are discussed In addition, residual Ca(OH)2 content obtained by DTA/TG investigations suggests the importance of portlandite presence in case of blended binder formulations as a vital parameter related to carbonation resistance.

OR-61

Steel reinforcement in slag containing binders and its susceptibility to chloride-induced corrosion

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The construction industry has moved from using plain-Portland cement (PC) to binders with high proportions of supplementary cementitious materials such as blast furnace slags such as CEM II, CEM III A/B, alkali-activated slags (AAS). The reducing nature of the blast furnace is retained by the slag, which contains ˜1–3 wt.% sulfur (expressed as SO3), mostly in a reduced state and available to dissolve when mixed with water or an alkaline solution. The pore solution chemistry of most modern 'alternative' construction materials can be characterised as being rich in reduced sulfur species, and highly alkaline. There remain many open questions about the influence of such alkaline-sulfide solutions on the passive film formed on common mild steel reinforcement, and thus the susceptibility of this steel to chloride-induced corrosion. This study focusses on the influence of reduced sulfur species on mechanisms of passivation of steel and the phenomena of localised corrosion due to chlorides in highly alkaline electrolyte solutions with containing varying concentrations of reduced sulfur species, via electrochemical and spectroscopic techniques. The passive film formed on the steel is an assemblage of Fe(OH)2 and Fe-S complexes, instead of the conventional Fe (III) oxide film that forms in contact with sulfide-free alkaline solutions. In alkaline-sulfide solutions, the critical chloride concentration to induce corrosion was found to be dependent on the concentration of sulfide (i.e. the reducing capability of the electrolyte), and on the time that steel specimens were exposed to the electrolyte, consistent with the progressive formation of a protective sulfidic layer on the steel.

OR-62

Influences of the combined application of polysaccharides and superplasticizers on early hydration of cement

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Organic admixtures are an indispensable component of modern concrete. Thus, their purposeful application is not only technically and economically viable but in addition an inevitable tool to make concrete more environmentally friendly. In this context, the use of polysaccharides has increasingly gained interest in the built environment as sustainable resource for performance enhancement. However, due to its origin, biopolymers possess a vast variety of molecular structures which can result in incompatibilities with other polymers present in concrete, such as plasticizers. The present study highlights effects of the joint application of different polysaccharides such as diutan gum and different types of starches and polycarboxylates with respect to their influence on cement hydration, binding capacity of calcium ions and structural build-up of cement pastes.

Construction, maintenance and modelling

Wednesday Afternoon Track C - S21
Apr 21, 13:00 - 14:00

OR-63

Numerical Modelling of Concrete Beam Reinforced with FRP Bars Subjected to Bending Until Failure

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The topic of this paper is numerical modelling of concrete beams reinforced with FRP reinforcement and comparison of the results with experimental ones. Numerical models of concrete beams subjected to bending until failure, reinforced with steel, GFRP or CFRP reinforcement have been made. The finite element method was used, and the models were made in Midas FEA software. Concrete is modelled by the total strain crack theory. A smeared cracks model was used. Steel is modelled as Von Mises material, while FRP behaviour is linear elastic. The interface between the reinforcement and the concrete was also modelled, as bond – slip function. The goal is to compare the results obtained by numerical models with the results obtained by experiments, which were elaborated in previous work of first author. Experimental results contain material properties of used materials: concrete, steel and FRP reinforcement and bond slip behaviour between reinforcement and concrete. The results showed that it is possible to obtain similar results obtained by experimental research, but very important is knowledge of material behaviour and modelling of it.

OR-64

Evaluating the impact of age on the behaviour of sfrc during flexural loading

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IRMA Institute for Research in Materials and Applications, Slovenia

The paper gives and evaluates the results of flexural tests of 3-day-old to 4-year-old Steel Fibber Reinforced Concretes (SFRCs). Flexural behaviour of SFRC was measured on beams with dimensions 100 × 100 × 400 mm (span length of 300 mm). A static four-point flexural configuration was used for measurements in accordance with the Japanese standard JSCE-SF4. Deflection measured at midspan increased with a constant rate of 0,5 mm/min during the testing. The parameter that was used to evaluate the impact of age on the behaviour of SFRC during flexural loading is equivalent flexural strength b. It is proposed by JSCE-SF4 and calculated by considering area under load-deflection curve up to the deflection of L/150 = 2 mm (span L = 30 cm). In addition, the impact of age on the behaviour of SFRC during flexural loading was further evaluated by ductility factor 1/B. It is a parameter for evaluating the behaviour of SFRC, which considers the entire surface under the load – deflection curve. Both parameters (b and 1/B) show a similar impact of age on SFRC behaviour. A slightly different estimate of the impact of age is obtained when the equivalent strength is considered, which is calculated from the surface under the load-deflexion curve to the characteristic deflexion of fracture zone , which also varies with the age of the SFRC.

OR-65

Modelling the durability of novel cementitious materials exposed to the drying and carbonation

Yushan Gu[1], Alisa Machner[2], Marie H. Bjørndal[2], Klaartje De Weerdt[2], Aljoša Šajna[3], Lucija Hanžič[3], Benoit Bary[1]

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The behaviour of novel cementitious materials (low clinker cement CEM II/C and CEM VI) exposed to CO2 is simulated and investigated with a simplified model in this paper. Based on studies of the evolution of the phase assemblage obtained from GEMS, the carbonation process is simplified into the dissolution of one combined Ca-containing phase and the precipitation of calcite phase. The purpose is to quantify some physical variables representative of the reactive transport properties: saturation degree for drying, porosity, calcite and Ca-containing phase content for carbonation. The dissolution rate of the Ca-containing phase and corresponding precipitation of calcite are assumed to be determined by the saturation degree, the partial pressure of CO2, and the concentration of calcium in solid phases. The carbonation process is assumed to be ruled by two phenomena: the water migration through the connected porosity and the diffusion of carbon dioxide in the gaseous phase, which are governed by two mass conservation equations. This model is solved by the finite element code Cast3M, and is verified using experimental data from carbonation depth measurements using a pH indicator, portlandite and carbonate profiles from thermogravimetric analysis and drying experiments on mortar and concrete.

OR-66

Flexure Behaviour of High Strength Concrete with Steel and Polypropylene Fibers

Natalija Bede, Silvija Mrakovcic

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High strength concrete (HSC) is very often used in structural design due to its numerous advantages in comparison to ordinary concrete. However, HSC has a major disadvantage, high brittleness. In general, addition of fibres to concrete mixture increases ductility. Hence, to overcome limitation of HSC steel fibres and combination of steel fibres with different volume fraction of polypropylene fibres (PP) were added to concrete matrix. The main purpose of this work was to investigate the effect of

the addition of hybrid steel-polypropylene fibres on flexure behaviour of concrete. Based on three-point bending tests flexural strength and flexural toughness are experimentally determined. Further, load-displacement curves and typical failure mode from flexural tests are given. Moreover, standard cube specimens were tested to determine the compressive strength. All above mentioned properties are compared with referent concrete.

POSTER PRESENTATIONS' ABSTRACTS

Posters

Poster Session Track
Apr 20, 9:15 - Apr 21, 17:00

PO-01

Behaviour of External Thermal Insulation Composite Systems (ETICS) in terms of water absorption throughout their lifetime

Andreja Pondelak[1], *Lidija Korat*[1], Primož Plešec[1], Danijel Lisičić[2], Sabina Jordan[1]

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The main function of External Thermal Insulation Composite Systems (ETICS) is to provide higro-thermal protection of the building and to improve its energy balance. For such system to perform efficiently throughout its entire life span, the properties of the rendering system (base coat and finishing coat) in terms of water absorption are crucial. However, this protective function may be limited with the ageing.

In order to study the effect of aging, our first task was to evaluate the performance of the samples with the base coat. Samples manufactured by JUB were exposed to accelerated aging and then tested according to procedure of determination of the resistance of external wall systems to driving rain under pulsating air pressure. The results of the measured water uptake showed that all aged samples absorbed less water than non-aged samples. Regarding that, additional laboratory investigations have been made by X-ray powder diffraction (XRD) and FT-IR spectroscopy to determine the changes in phase composition. Hg-porosimetry was used to analyse the changes in pore size distribution, while scanning electron microscopy (SEM) coupled with EDS was used to examine the changes in morphology and to determine the mineral composition.

It was found that lower water uptake of aged samples was caused mainly due to the changes in the sample surface. This was demonstrated by SEM analysis where non-aged samples have an undefined structure while the aged samples have defined crystalline one. The resulting rhombohedral particles, with the size of approximately 0.4-4 µm, are calcium carbonate (calcite), as shown by EDS. Higher proportion of formed calcite on the surface of aged samples compared to the surface of non-aged ones was confirmed by FTIR spectroscopy, XRD and by the EDS analysis.

PO-02

Resistance of Concrete Made with Finely Milled Cathode Ray Tube Glass as a Supplementary Cementitious Materials to Sulphate Attack

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Sustainable building is one of the key requirements in contemporary civil engineering aimed at reducing the harmful impact on the environment. Since the turn of the twenty first century, it has been insisted on usage of recycled materials which could, at least in part, substitute traditional materials. Even though the TV sets with cathode ray tubes are no longer being produced, the amount of cathode ray tube glass (CRT) on the waste disposal sites has still been increasing.

The goal of experimental research was determining potential for usage of finely milled CRT glass as a supplementary cementitious material and checking resistance of such concretes on the sulphate action. Six experimental batches of concrete were made. The replacement percentage of cement with CRT was: 5%,10%, 15%, 20% and 35%, by cement mass. Each batch consisted of 18 cylindrical specimens with a diameter of 100 mm and height of 100 mm. A half of specimens was cured in saturated solution of calcium-hydroxide until the test. The second half of specimens was kept for the first 28 days in the saturated solution of calcium-hydroxide, after which they were exposed to action of 5% solution of sodium-sulphate. Assessment of durability of concrete to sulphate action was performed by the visual evaluation of concrete appearance and by testing the variation of compressive strength of treated concrete specimens at the age of 3, 6 and 12 months.

PO-03

Properties of light-weight self-compacting concrete for precast walls with improved energy efficiency

Violeta Bokan Bosiljkov[1], David Antolinc[1], Andreja Padovnik[1], Tjaša Zupančič-Hartner[2]

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The paper will present physical and mechanical properties of light-weight self-compacting concrete (LSCC) with designed density below 1600 kg/m3 and designed 28 day compressive strength class, according to EN 206 not lower than LC 15/16.

Low density of the LSCC mixture was obtained using expanded clay aggregate grains with density of about 650 kg/m3 and high air content of the hydrated cement paste. Adequate viscosity of the mixture in the fresh state and high enough compressive strength in the hardened state were obtained using cement CEM I 52.5 R, low water-to cement ratio and PCE superplasticizer. Reometer ConTec Viscometer 5 was the main tool when designing fresh concrete properties that assure concrete self-compacting ability and adequate stability.

High porosity of the hydrated cement paste and incorporation of expanded clay aggregate grains considerably lowered the E-modulus of concrete (17.5 GPa) and at the same time improved energy efficiency of the LSCC, compared to the normal weight reference SCC composition. However, drying of the LSCC is much slower, compared to the reference SCC, due to high water retention capacity of the lightweight aggregate. Capillary porosity and water vapour diffusivity of the LSCC, on the other hand, are about the same as for the reference composition.

PO-04

Sensors for long-term control of relative humidity and temperature inside concrete and mortar

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The purpose of the study was functionality testing of a custom made sensor system, which could be used for long term measurements of the temperature and relative humidity inside mineral composites with alkaline binders, such as cement, cement-hydrated lime or pure hydrated lime binder.

Long-term functioning of the SHT sensors was studied using three different composite mixtures: lightweight self-compacting concrete (LSCC), cement-hydrated lime masonry mortar and pure hydrated lime mortar. The LSCC was cast into specially prepared moulds to simulate wall of prefabricated bathroom, whereas the two mortar compositions were used to build masonry prisms made of 3 clay bricks and two mortar joints to simulate conditions in masonry walls. The prepared sensors were positioned at the centre of each element; concrete wall (2 parallel specimens) and mortar joint (2 joints per mortar composition), and were later, during the casting, covered by fresh mixture. The ALMEMO sensor system was used as a reference system only in the concrete specimens, because the inclusion of a special tube with the protection of sensor at the top of the sensor was not possible for the mortar joints.

PO-05

Influence of Drying Methods in Alkali Activation of Waste Casting Cores

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Alkali activated materials are a potential future solution in the building industry since they address the scarcity of available raw materials and larger and larger amounts of waste materials which can be used as the precursors in alkali activation technology. Namely, only those waste materials that have enough Si and Al in the amorphous phase can be utilized in alkali activation technology. Si and Al form an aluminosilicate network where both Al3+ and Si4+ are in tetrahedral coordination, which leads to the need for balancing the charge for Al3+ with elements from the 1st group.

Waste casting cores are residue from the foundry industry. There are several types of cores depending on the technological process and specifically casting temperature: hot box, shell box (warm box), and cold box. Waste produced with shell box method, where binder hardens with heat only the outer layer of the sand core, was activated with NaOH and Na-water glass, cured at lower conditions, and dried at room conditions at 110 °C and volumetrically with microwaves.

Samples, where precursor was ground and sieved once below 600 µm or below 90 µm, did not show any positive results at room temperature. However, with curing at 110 °C or with microwaves, samples dried, solidified, and, in the case of foamed structure, they kept pore distribution stable. The highest compressive strength, 25 MPa, was gained with curing at 110 °C. Lowest density, 0.5 kg/l, with compressive strength above 3 MPa was achieved with treating with microwaves.

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PO-06

Effects of Waste Glass in Properties of Concrete

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There is a limit on the availability of natural aggregate used for making concrete mix, and also an environment imposition to reduce energy consumption and gas emission resulting from construction processes. A potential solution of this problem are considered thought usages of waste glass as partial replacement of natural coarse and fine aggregates in concrete mixes. Among the various waste materials, glass is considered a good substitute for natural sand due to similarities in physical properties and chemical compositions. The effect will be oriented in replacement of aggregate in optimal percent to achieve the requested parameters in concrete or improvement of specific properties. In order to account the numbers of variables and establish a clear approach, various parameters such as sand grading, source of waste glass, design mix and chemical analyses are taken into consideration. This study elaborates the property of fresh and solid state of recycled glass concrete, focused on silica reactivity, grading of recycling glass and fine modulus. This paper gives an overview of the current progress and recycling process of waste glass and using the waste glass as replacement of aggregate and through this we tend not only help in the reuse of waste glass but also create a greener environment.

PO-07

Electrochemical corrosion tests on steel in alkali-activated materials

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One of the potential alternatives to Ordinary Portland Cement (OPC) are Alkali-Activated Materials (AAMs). The service life of reinforced concrete structures greatly depends on the corrosion resistance of embedded steel reinforcement. Due to the wide range of AAMs and their diverse properties, corrosion processes of steel in these materials are relatively unknown. Corrosion monitoring methods or their interpretations in certain cases cannot be directly transferred from the ones for OPC materials. The chemical compositions of pore solution in different AAMs

influence the results of electrochemical measurements and their interpretations. Within this research, three different alkali-activated mortar mixes were prepared, based on fly ash, slag or metakaolin. Pore solutions were extracted from each mortar and chemical analysis was acquired. Different electrochemical corrosion measurements were performed on steel submerged to synthetic pore solutions. In parallel, ordinary carbon steel reinforcing bar was installed in the same types of alkali-activated mortar mixes. Specimens were exposed to wet/dry cycles with saline solution and periodic measurements of electrochemical impedance spectroscopy (EIS) were performed. Measured parameters in both systems were analysed and compared. It was concluded that electrochemical measurements in pore solutions can provide basic overview on corrosion behaviour in different AAMs environments. Periodic EIS measurements enabled monitoring of corrosion initiation and propagation on steel reinforcement in AAMs, although the information on the corrosion type is missing. Interpretation of results depends on visual analysis of corrosion damages after the end of exposure, providing information on corrosion type and intensity. The continuation of research on corrosion monitoring techniques will be performed by using Electrical Resistance (ER) sensors and Coupled Multi-Electrode Array (CMEA) sensors.

PO-08

Microstructural investigation of phosphogypsum based ternary system binder

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The construction industry is developing through the implementation of global trends, such as the problem of conservation of earth resources, which with each passing day becomes more relevant. Reduction of waste and its harmfulness from extractive industries and amending is set as goal of European Parliament and the Council by directive 2006/21/EC, which can be carried out by using waste in the production of building materials. A promising example and in the same time challenging material is phosphogypsum (PG) – gypsum waste coming from fertilizer production plants, which could be used as a potential replacement of natural gypsum. Since there are legislation limits and prejudice coming from society regarding to PG, direct use of PG as substitution of natural gypsum products is problematic. Solution offered in this paper in utilization of PG is associated with the development of an advanced and new type of binder which has much lower carbon footprint comparing to Portland-cement while the strength properties are similar to Portland cement. A ternary binder based on PG, waste metakaolin and Portland cement was researched in this study. Proposed material could contain up to 70% of PG while the optimal design of ternary binder (50 wt% of PG) composition in water-saturated conditions could give compressive strength up to 50 MPa at the age of 28d. Binder microstructure, chemical and mineralogical composition was investigated by SEM, EDX and XRD. Results of ternary binder was compared both for PG and commercially available gypsum plaster in composition. Presented material proved to be competitive binder to create composites such as mortars similar to materials based on traditional Portland cement.

PO-09

The Design of New Sustainable Cements Using Wastes and Bio-derived Organic Additives

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Alkali activated materials are a promising opportunity to enable the valorisation of wastes while yielding high performing alternative cements. The uptake of these cements, which can be designed to offer attractive environmental footprints, has been limited in part due to their high viscosities and consequently poor workability. This study aims to design flowable fresh pastes from blast furnace slag and fly ash activated cements without compromising their strength development. This is achieved by the use of abundant, inexpensive and renewable bio-derived organic lignosulfonate admixtures. The study of the mechanism of action of these admixtures further contributes to the understanding of the binder chemistry and the design of low cost, low CO2 cements with technical characteristics that are desirable in modern construction industries. Blast furnace slag and fly ash were activated with sodium silicate and sodium hydroxide solutions; scanning electron microscopy and X-ray diffraction were used to characterise these materials before and after activation. A low sugar, calcium lignosulfonate (LS) derived from softwood was added immediately upon activation and mini-slump tests, setting time and rheology tests were carried out to demonstrate the influence of this organic additive on the fresh-state properties of these alkali activated pastes.

PO-10

Design of a Conference Gift for the CoMS 2020/21

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The Sitarjevec mine in the town of Litija, Slovenia, is known for its ancient history of ore mining. Nowadays the mine is abandoned, but the local community has recognized the tourist potential of the mineral-rich mine, which contains some of the fastest growing dripstone structures in the world. An unexpected colour appears in certain areas of the mine as a consequence of mine mud deposits. These unique characteristics of the mine were a source of inspiration in the process of designing new products for tourists. Larger mine mud deposits in the abandoned mine shafts are considered as waste material, but, with its surprising colour, mine mud has been recognized as a source of pigment. To determine its recycling potential, pigment from the mine was investigated in terms of its suitability for textile printing at the Slovenian National Building and Civil Engineering Institute. Following pos-

itive results, the pigment was used as a textile printing colorant in the design of a conference gift. The design process combined the design of patterns visually related to the heritage of the mine and the surrounding area with the use of pigment from the mine and product design. The goal was to develop a product suitable for the office environment. As a result, a unique gift for the CoMS 2020/21 conference was developed. The gift should serve as a tangible reminder of the event – something people will keep and use in their office. It should be practical and useful, as well as tell a story of its production, meaning and design. The design process was centered around the creation of a low-cost yet original, crafted and sustainable conference gift. A pencil holder requiring self-assembly was designed, that allows the user to be part of the final design / process of realization.

PO-11

Assessment of Social Effects in Asset Management

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The transnational European CEDR project ISABELA (Integration of social aspects and benefits into lifecycle asset management) was launched to define a common basis for social impact assessment in asset management. The aim was to define a holistic asset management framework for social key performance indicators (S-KPIs) and to model social benefits in terms of social effects (monetary and non-monetary), social backlog and social risk. These project results are becoming increasingly important in the context of evaluating different maintenance strategies for road infrastructure networks. While decision makers need to present the consequences of their maintenance strategies and policies on both technical and social levels, ISABELA showed how social aspects can be an integrated part in asset management frameworks, how to present social impacts and how to discuss maintenance needs using social aspects. The project aimed to identify clear and justifiable social key performance indicators in combination with existing technical parameters, taking into account different stakeholders and their needs and expectations. To this end, ISABELA considers maintenance aspects such as traffic availability, disturbance and efficiency (travel time, vehicle operating costs, etc.), road safety (fatal and serious accidents related to asset condition), environment (noise, air pollution, natural resources, etc.) and socio economy (asset value, wider social effects, etc.). In addition to the S-KPIs, ISABELA proposed a decision-making process for the selection of appropriate parameters and models, and demonstrated the assessment of social effects with practical examples.

PO-12

Influence of different types of fibers on the ultimate and residual flexural strength of sprayed concrete

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TThe influence of the application of different types of fibres on the flexural strength of beams cut from slabs of sprayed concrete is presented in the paper. Fibres of different materials, shapes and dimensions were used. All types of concrete were made of the same component materials and composition, except the amount of fibres that is varied. Slabs of dimensions 60x60x10 cm were made using a concrete spraying machine. After curing, the beams of 75x125x500 mm were cut from the beams. Flexural strength of beams was tested according to SRPS EN 14488-3 at the age of 28 days. Based on the test results, depending on the type, shape, amount and distribution of fibres, values of ultimate and residual strengths were analysed. The highest values of ultimate and residual strength at deformations of 0.5-1, 0.5-2 and 0.5-4 mm had sprayed concrete (or shotcrete) with the addition of 40 mm polypropylene fibres.

PO-13

Energy efficiency improvement and fire safety of high-rise residential buildings' façades

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In the second half of the XX century several dozens of high-rise residential buildings were built in Novi Sad, with different variants of external walls. After years of exploitation and lack of regular maintenance, there is a need for renewal of their facades in order to comply with the requirements of contemporary technical regulations and standards. The problems of buildings' thermal renewal are closely related to fire safety issues, thus applied solutions have to meet both the energy efficiency and fire safety requirements. Within the first part of the paper, evolution of Serbian regulations in the field of thermal protection and fire safety of façades is presented. In the second part an analysis of the possibilities for improving the energy performance of high-rise residential buildings in Novi Sad, through a case study, was carried out. The issue of optimal thermal insulation material selection in the façade renewal process was considered.

PO-14

Application of terrestrial laser scanning methodology in façade reconstruction and rehabilitation projects

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In recent years, the need for spatial data and products that can be obtained by processing them has been increasing. As a result, there is a tendency to collect data as

quickly as possible, which led to the development of new methods, as well as to the improvement of the quality of the final products. In addition to saving time, tendency is also to collect data of more accuracy, higher density, extraction of as diverse information as possible based on the collected data, etc. Moreover, high demand exists in developing the devices and platforms by which raw spatial data is collected. Specifically, their features are getting better, the devices are getting smaller and more compact, and ultimately, cheaper, making them significantly more affordable and attractive to users. Terrestrial laser scanning enables quick and easy collection of spatial geometric data. By using laser scanner, the area of interest is surveyed with high frequency. Based on the collected data, the position of each point in the 3D local coordinate system is determined. In addition, it is possible to perform georeferencing of spatial data, i.e. defining them in the state coordinate system. The paper gives a brief overview of terrestrial laser scanning technology, methodology of data collection and processing for the needs of digitization of facades with a high level of detail.

PO-15

Facade Fire Safety – Legal Framework in Serbia, Croatia and Slovenia

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Fire safety is one of the basic requirements buildings should meet during exploitation period. In recent years, facade fires took dozens of human lives and caused great material damage. In the last two years, Serbia's fire safety regulations have been significantly improved, in line with Serbia's commitments to the EU accession process. Regulation on Construction Products EU defines the minimum requirements that must be implemented into national legislation of EU member states and countries in the process of joining the EU. The performance of building materials, and especially the reaction to fire, which are part of the exterior walls of buildings may significantly affect the possibility of spreading fire on the façade of the building, as well as the transfer of fire to adjacent rooms in the building affected by the fire.According to previous research studies on fire safety regulations for housing in Europe, there is still broad variety of systems of technical requirements for buildings in the various European countries, despite the existence of the Regulation on Construction Products and the development of Euro Codes. The goals and topics are quite similar, but detailed study reveals considerable variety of functional requirements, performance requirements, and specifications, with inconsistency within the requirements of some countries. A comparative analysis of fire safety requirements for residential building façades in Serbia, Croatia and Slovenia is performed in the paper, according to the current legislation in all three countries, in order to evaluate the need for further fire safety improvements. This article focuses on the analysis of fire safety of facades, in order to identify differences in both levels of requirements and strategies that may be significant in practice.

PO-16

Degradation of Tension Stiffening due to Corrosion – an Experimental Study on Cracked Specimens

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In this work an experimental research will be presented in which cracked reinforced concrete specimens were exposed to accelerated corrosion and tested in uniaxial tension in order to investigate the degradation of tension stiffening due to reinforcement corrosion.

Experiments on reinforced concrete tension specimens with corroded reinforcement have already been performed by many authors. Usually, the reinforcement corrosion is induced through an external current power supply and the specimens don't have cracks when the accelerated corrosion is induced. Disadvantage of the tension stiffening obtained in this manner lies in the fact that concrete in structures usually subjected to bending or/and axial force already has cracks perpendicular to longitudinal reinforcement, and that corrosion induced by galvanostatic method (which causes mostly homogeneous reinforcement corrosion) does not represent the actual corrosion process under natural environment (localised corrosion).

The concrete specimens are reinforced with a single bar running longitudinally through the centroid of the cross-section, and exposed to reinforcement corrosion in a cyclic corrosion test chamber by exchanging wet (salt water) and dry (heating) cycles, simulating sufficiently representative the natural process of corrosion. Before exposing the reinforced concrete specimens to accelerated corrosion, cracks are introduced into the specimens. Consequently, this cracks have significantly deteriorated the bond in the vicinity of the cracks.

Testing was conducted on both corroded and controlling un-corroded specimens, and a relationship between the applied load and mean strain of the cracked specimens was established. This model should be closer to the nature of a great number of reinforced concrete structures subjected mainly to bending, meaning that the cracks form in the concrete already at the beginning of the exploitation of the construction, i.e. well before the corrosion process has started.

PO-17

Valorisation of selected secondary raw materials for low-CO2 cements

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Valorisation of secondary raw materials is being intens-

ively investigated in the development of alternative mineral binders in the cement industry. A promising way of recycling secondary raw materials is the synthesis of belite-sulfoaluminate cement clinker. Due to the higher amount of aluminium needed for their production in comparison to common cements, valorisation needs to be performed first. The aim of valorisation is to determine the aluminium-containing residues that have a high potential to partially or fully replace the limited and often expensive source of aluminium, i.e. bauxite that is currently used. On the other hand, huge amounts of various industrial and mine waste in East-Southeast European countries could represent a potential source of secondary raw materials. Thus, in the first phase of the RIS-ALiCE project, different types of steel slags, ash, red mud, paper sludge, bauxite and metal mine tailings, have been identified. This study will present the results of the characterization of different previously-collected secondary raw materials, using various analytical methods such as X-ray fluorescence spectroscopy, ICP optical emission spectrophotometry, gravimetry, X-ray powder diffraction, gamma spectroscopy, etc. Samples were characterized with respect to their chemical (main elements, trace elements, moisture content, mineral composition, presence of organic matter), physical (granulometry, BET specific surface area, specific weight bulk density) and radiological composition (content of radionuclides 40K, 226Ra and 232Th). Based on all these parameters, the potential of aluminium-rich residues for a low-CO2 cement based on belite-sulfoaluminate clinker will be assessed. As a secondary objective of the RIS-ALiCE project, a detailed database (register) of Al-rich secondary sources in the ESEE Europe will be created and will serve as a link between the holders/producers of secondary raw materials and potential end users.

PO-18

Non-destructive evaluation and monitoring cement concrete-an experimental approach

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In last few decades, the non-destructive evaluation and structural health monitoring (SHM) of civil infrastructures have gained popularity with the advent of smart material and better sensor integration with the structural systems. Cement concrete system is heterogeneous nature and its strength development is very complex. Therefore, this paper studied the continuous monitoring of the concrete strength using two NDT & E method (UPV and Rebound Hammer) and Piezo-impedance based structural health monitoring (PISHM). The embedded piezo sensor (epoxy coated piezo sensor) is used for this study. Lab-based concrete samples are cast along the embedded sensor and monitored for 30 days of air curing. The continuous strength monitoring concrete specimen is done for 30 days using both NDE techniques and smart materials (Piezo Sensor) based evaluation. The overall results obtained from the three tests were compared for better evaluation for the robust strength monitoring technique.

PO-19

Use of Steel Slag for the Synthesis of Belite-Sulfoaluminate Clinker

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Belite-sulfoaluminate (BCSA) cements are low carbon mineral binders, which require low energy consumption and allow the incorporation of various secondary raw materials in the clinker raw meal. In this study two types of unprocessed steel slags, coming from stainless steel production, were incorporated in the BCSA clinkers. The clinker phase composition, clinker reactivity, and the compressive strength of the cement were studied to evaluate the possible use of the slag in BCSA clinkers. The cement clinkers were synthesized by using natural raw materials, white titanogypsum, mill scale, as well as two different steel slags: (i) EAF S slag, which is a by product of melting the recycled steel scrap in an electric arc furnace, and (ii) ladle slag as a by product of the processes of secondary metallurgy, in various quantities. Raw mixtures with two different targeted phase compositions varying in belite, calcium sulfoaluminate and ferrite phases were sintered at 1250 °C. Clinker phases were determined by Rietveld quantitative phase analysis, while their distribution, morphology and incorporation of foreign ions in the phases were studied by SEM/EDS analysis. The clinker reactivity was determined by isothermal calorimetry. BCSA cements were prepared by adding titanogypsum. The compressive strength of the cement pastes was determined after 7 days of hydration. The presence of a predicted major clinker phases was confirmed by Rietveld analysis, however periclase was also detected. Microscopy revealed subhedral grains of belite and euhedral grains of calcium sulfoaluminate phases, while ferrite occurred as an interstitial phase. The results showed differences in the microstructure and reactivity of the clinker and cement, which can be attributed to varying amounts of ettringite due to different slag types.

PO-20

First experiences in the development of slovenian sustainable building indicators

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The construction sector is recognised as having a key impact on the life on Earth. Consequently, the EU has set clear environmental goals for 2030 and 2050, and is developing policies and tools to achieve them. One of the tools for achieving these goals is to establish a system for the evaluation of the environmental performance of buildings, with the priorities of reducing GHG emissions, saving with natural resources and preserving the environment, while maintaining sustainable development

and ensuring a healthy living environment. Slovenia has joined in achieving this goal with a study on the state of play, commissioned a few years ago by the Ministry of the Environment and Spatial Planning, as the starting point for the development of sustainable building indicators (SBIs). The research, which included an analysis of the Slovenian legislation, commercial certification systems for sustainable buildings and development in the field of green public procurement, exposed complementary but rather different goals and views. It further showed that the Level(s), which provides a common EU approach in assessing the environmental performance of buildings, seems to be the most appropriate framework and the basis for the development of the Slovenian system of SBIs. The development of the Slovenian SBIs is currently underway within the project LIFE IP CARE4CLIMATE with the preparation of guidelines, data sources and procedures for determining the value of individual indicators for the assessment of buildings. Initial research with key construction stakeholders has shown that the solution must be linked to the national building legislation, computational methods and software tools, and also to the established planning procedures. The analyses have also shown that, parallel to developing such a system, it is essential to provide a functional supporting environment and a specific, purposely designed information platform to connect the stakeholders with the developers of the sustainable building indicators system.

PO-21

Properties of concrete curbs with recycled aggregate from precast elements

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The paper presents the possibility of using recycled aggregate from precast concrete paving elements and curbs in the production of concrete curbs. Experimental work included several types of concrete consistency class S1, made with different amounts of cement and coarse recycled concrete aggregate. The influence of percentage and grain size of recycled concrete aggregate on concrete compressive strength at different ages was observed. Based on the experimental results, it can be concluded that the use of recycled concrete as an aggregate creates a new composite material that can be used for the production of precast elements. The results show that the replacement of the coarse natural aggregate with aggregate from crushed concrete is possible to produce concrete curbs that meet the requirements of EN 1340, but the class depends on the replacement percentage of the natural aggregate with recycled ones. In this way, the production waste is turned back to process, and the newly created concrete is certainly ecological material.

PO-22

Assessment of the condition and repair of the culverts on the highway

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The structures used to pass ditches, streams and canals below the roads are culverts. They are small bridge structures of openings up to 5.0 m. This paper presents the analysis of the culverts of different cross sections on the highway of the Niš District. It is given a brief description of each culvert with the defined types of damage observed during the assessment, and the proposals for the repair of this type of structure. About 25 culverts were surveyed where different types of cross sections appeared, ie tubular, plate, arched and a combination of these three types of culverts. After the analysis, it was concluded that all culverts should be regularly maintained, while for some culverts a complete reconstruction of the inflow or outflow head should be done.

PO-23

Use of Sargassum (Brown Seaweed) Bio-waste in Construction Materials

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Sargassum is a brown seaweed polluting in massive quantities several seashores around the world. Currently, this bio-based waste product is being removed from touristic sectors, where is normally buried or discarded in abandoned areas. However, limited knowledge is available about the potential benefits of this bio-waste in construction industry. Sargassum contains polysaccharides that are well-known to positively influence the performance of cement and concrete.[1-3] Some polysaccharides had rather fluidizing effects, others rather stabilizing effects and others strong thixotropic effects. The incorporation of a rapid structural build-up in the very early stages of casting of concrete (by thixotropy) is one of the major challenges today in conjunction with more and more efficient and computerized technologies, as it helps to accelerate the production and supports additive manufacturing processes.[2] The aim of this investigation is to extract the different types of polysaccharides present in several sargassum species found in the Mexican Caribbean region and to study their effect on the rheology of cement. Furthermore, the pozzolanic effect of sargassum residues are also tested and their impact as co-fuel cement to minimize the energy and raw materials demand to reduce CO2 emission.

[1] W. Schmidt, H.J.H. Brouwers, H.-C. Kühne, B. Meng, Interactions of polysaccharide stabilising agents with early cement hydration without and in the presence of superplasticizers, Construction and Building Materials, 139 (2017) 584-593.

[2] W. Schmidt, M. Alexander, V. John, Education for sustainable use of cement based materials, Cement and Concrete Research, 114 (2018) 103-114.

[3] Y. Peng, E. Xie, K. Zheng, M. Fredimoses, X. Yang, X. Zhou, Y. Wang, B. Yang, X. Lin, J. Liu, Y. Liu, Nutritional and Chemical Composition and Antiviral Activity of Cultivated Seaweed Sargassum naozhouense Tseng et Lu, Marine Drugs, 11 (2013) 20-32.

PO-24

Appropriate sound insulation of facades as a measure to ensure acceptable acoustic comfort in residential buildings

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Wherever possible, the environment with residential buildings should be protected from the effects of noise sources by environmental noise reduction measures. If such measures cannot reduce the noise level in the environment to an acceptable level, acceptable acoustic comfort in the residential buildings shall be ensured by adequate sound insulation of the facades, which is the main topic of this paper. The paper outlines some of the criteria for providing good acoustic comfort in the residential buildings, on the basis of which the conditions and necessary measures for providing sufficient sound insulation of the facade elements are discussed. Since, in addition to the noise from the environment, the acoustic comfort in apartments is also affected by the noise from adjacent apartments in the building, the link between the sound insulation performance of facades and audibility of the speech noise form adjacent apartments is also discussed.

PO-25

Condition and repair assessment of the culverts on the main roads

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Culverts are structures used to pass ditches, streams and canals below the roads. By definition, they are classified into smaller structures (bridges) of openings up to 5.0 m. In this paper the culverts of different cross sections, on the main road of the Raška District, were analyzed. A brief description of each culvert was given, with the defined types of damage observed during the visit, or assessment. Also, the suggestions are given for the repair of this type of structure. About 60 culverts were surveyed where different types of cross sections appeared. Tubular, plate, arched and a combination of these three types of culverts were analyzed. After the analysis, it was concluded that all culverts should be cleaned, arranged around the inflow and outflow, as well as repairing of minor damage caused by weather changes. In some culverts, in addition to the regular maintenance, a complete reconstruction of the inflow and outflow of the culverts must be done as well as the replacement of the concrete culvert parts.

PO-26

Experimental carbonation study for durability assessment of novel cementitious materials

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The design process of concrete structures is carried out using standards and guidelines, while the durability predictions of concrete structures is supported only with exposure classes and experience-based requirements. To improve durability predictions of the carbonation resistance of concrete, a numerical model is being developed within the Horizon 2020 project EnDurCrete, coupling the rate of carbonation, and the drying rate. To verify the numerical model, an accelerated carbonation study was carried out. Experiments were conducted on mortars incorporating a novel CEM II/C (S LL) cement, developed within the EnDurCrete project, and a commercially available reference cement CEM II/A S. EnDurCrete mortars (EnM) and reference mortars (RefM) were prepared with water-cement ratios of 0.6 and 0.5 (denoted with label extensions -06 and -05). Visual assessments and thermogravimetric analysis (TGA) were used to measure the carbonation rates, which were found to be ˜1.0 mm day-0.5 in EnM-06 and ˜0.6 mm day-0.5 in RefM-06, while in EnM-05 and RefM-05 the values were ˜0.7 and ˜0.2 mm day-0.5 respectively. Additionally, TGA shows that the initial portlandite (CH) content is ˜1.5 wt% in EnM-06 as opposed to ˜3.0 wt% in RefM-06. The difference in the initial CH content in the two hydrated binders might explain the difference in their carbonation rate. During the moisture transport experiments a gravimetric method was used to determine mass changes as specimens underwent drying and resaturation with and without CO2 present. The drying led to a decrease in mass, but in the presence of CO2 this mass loss was compensated by the mass gain due to uptake of CO2 during carbonation. The resaturation experiments indicate an increase in the suction porosity in the carbonated samples compared to the non-carbonated samples.

PO-27

Effect of Accelerated Carbonation on the Efficiency of Immobilization of Cs in the Alkali-Activated Blast Furnace Slag

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In this paper the effect of accelerated carbonation pro-

cess on the effectiveness of immobilization of cesium (simulated radioactive and toxic waste) in the alkali-activated blast furnace slag (AABFS) matrix was studied. Blast furnace slag (BFS) was contaminated with 2% and 5% Cs (with respect to the dry BFS mass) and alkali-activated with sodium silicate solution, while the AABFS samples were cured sealed in plastic envelopes for 24 h at 95oC. First series of AABFS samples were exposed to accelerated carbonation (open curing), while the second (reference) series of AABFS samples left to aging (also sealed) at room temperature until testing. Thereafter AABFS samples were subjected to a short-term (five-day) leaching tests according to the ANSI/ANS-16.1-2003 standard. The strength of AABFS mortars were tested according to the SRPS EN 196-1 standard, while the carbonation was confirmed by phenolphthalein test and SEM analysis. The diffusion coefficient (D) and non-dimensional leachability index (L) of cesium leached from AABFS were calculated according to the ANSI/ANS-16.1–2003 standard. A correlation between the accelerated carbonation process and the effectiveness of immobilization of cesium in AABFS was established.

PO-28

High volume cement replacement by biomass ashes in cement-lime mortar

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Cement-lime mortar is used for a wide range of construction works and products around the globe, hence conserving natural resources used for its production is of a great importance. Recent literature works indicate that ashes generated by combustion of harvest residues can be used as SCM materials in cement-based composites, thereby saving energy, reducing CO2 emission and contributing to cost effective and cleaner environment. In this research work, three types of biomass ashes were used as cement replacement in cement-lime mortar with 30%, 50% and 70% substitution: the ash generated by combustion of wheat straw (WSA), mixture of wheat and soya straw (WSSA) and mixture of wheat straw and sunflower husk. In addition, two types of fine aggregate were varied: standard quartz sand and sand for plastering of river origin. In this way, 20 different cement-lime mortar mixes with binder-lime-aggregate volume ratio of 1:1:5 were casted. Investigations were carried out on fresh and mechanical properties of mortar, which include: consistency of fresh mortar and compressive strengths of hardened mortar, at the ages of 28 and 90 days. The results indicate that it is possible to produce cement-lime mortar, blended with biomass ashes, with satisfying fresh and mechanical properties comparable with those of reference mortar.

PO-29

Analysis of the influence of temperatures due to concrete cosmetics of fair faced concrete

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The visual appearance of exposed concrete increasingly plays a central role. Material imperfections, construction errors, planning gaps as well as colour deviations are indications for poor coordination, communication or preparation. For the professional refurbishment of imperfections, there are countless possibilities of concrete repair including the "concrete cosmetics". As part of a project work at the Carinthia University of Applied Sciences the influence of temperature on concrete-cosmetic operations on exposed concrete was analysed. Three specimens were remodeled with the same mortar and each was stored at a different place with different temperature: outside, indoor, and in a refrigerator. Already after the first weeks, slight colour differences were detected. Several specimens stored outside and in the refrigerator showed a bright colouring, the specimens from the indoor conditioning retained a constantly dark colour. The specimens stored in the refrigerator showed a dark colouring at the beginning but turned brighter from week to week. Depending on the different temperature influences, the specimens got various colours even though the same products were used.

PO-30

Self-Sensing Properties of the Slag Geopolymer Composite with Graphite Powder under Flexure

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Development of smart materials is one of the great challenges for the sustainable building. New functionalities of common building materials can be achieved by the addition of conductive admixtures that reduce the electrical resistivity. Such composites gain the importance in the new field of applications that comprise self-sensing and self-heating materials or self-monitoring structures. This paper deals with the self-sensing properties of slag based geopolymer with graphite powder. The amount of graphite in the tested specimens was 3 and 10%, respectively. The self-sensing properties were tested under repeated flexural loading with constant amplitude in the configuration of three-point bending test. Both composites showed good sensing properties and reproducibility of the piezoresistive response to the flexural loading.

PO-31

Energy Efficiency in Residential Buildings in Kosovo

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Energy efficiency, is supposed to be the first step towards sustainability in residential buildings. In Kosovo, the residential sector is considered to be the largest user of energy consumption, characterized by a high degree of inefficiency. The main obstacles are the old buildings constructed during 70's, which in most cases have had no development in this regard. The same situation is considered to have continued after 1999, where due to the absence of legislation and proper inspections, buildings were built based on the free will of investors. Buildings in these periods are characterized by different rules of form and

structure in terms of orientation, materials, and construction techniques. Therefore, the initiative and willingness to intervene in the aforementioned residential buildings is considered to be more a social need, it is about identifying factors and choosing the optimal way to improve constructive needs while proving more reliable in the long run.
This article aims to illustrate the current situation of the existing buildings, and more specifically the constructions in these two periods, by attempting to analyse the constituent elements of the building envelope as constructive and thermal insulating. It will also attempt to compare the materials, construction techniques and building elements used previously with those that are more advanced nowadays.
In order to achieve the idea of sustainable buildings, some development steps are needed beforehand to improve them, therefore through qualitative research with specific project analysis and project documentation, will attempt to explore and compare residential buildings envelope of pre and post-war periods in terms of energy efficiency. Therefore, this article uses specific buildings to present a method of improving efficiency in other residential buildings in Kosovo and other cases that could be used as a model.

PO-32

Thermal compatibility of repair mortars based on fly ash as SCM according to EN 13687-1

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This paper presents the results of the experimental study on thermal compatibility of repair mortars based on fly ash as supplementary cementitious material (SCM) applied to the concrete substrate, determined according to EN 13687-1. Chemical composition of fly ash from a Serbian coal power plant was determined by XRF analysis. Repair mortar specimens were prepared with two "water-to-binder" ratios (0.4 and 0.5), Portland cement with 0%, 10% and 20% of fly ash as SCM and CEN standard sand. At the age of 28 days, the specially prepared specimens were exposed to 50 freeze-thaw cycles. The effect of fly ash on repair mortar tensile bond strengths after freeze-thaw cycling with exposure of specimen test face to saturated de-icing salt solution was investigated. Afterwards, the tensile bond strengths of repair mortars were determined by pull-off test. Based on the obtained results it is concluded that all mortars met the requirement for class R4 according to EN 1504-3.

PO-33

Use of marine bio-waste in construction materials

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Marine bio-waste pollutes several seashores around the world. Currently, this bio-based waste product is being removed from touristic sectors, where it is normally buried or discarded in abandoned areas. However, limited knowledge is available about the potential benefits of marine bio-waste in construction industry. Marine bio-waste contains polysaccharides that are notorious to positively influence the performance of cement and concrete.[1-3] Some polysaccharides display fluidizing effects, others stabilizing effects and others strong thixotropic effects. The incorporation of a rapid structural build-up in the very early stages of casting of concrete (by thixotropy) is one of the major challenges today in conjunction with more and more efficient and computerized technologies, as it helps to accelerate the production and supports additive manufacturing processes.

PO-34

Investigation and strengthening of a damaged eleven stories building in Dar Es Salaam

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An eleven stories building in the city of Dar es Salaam, experienced an abrupt crush of one of its edge columns at first floor level. The crush was accompanied with a loud noise like a small bomb. Due to this event, the Government cancelled the certificate of occupancy for it and other three adjacent buildings and requested that a thorough structural investigation be done and come up with an appropriate solution for reinstating the building. Following the said request, structural investigation was done through studying different parameters such as displacements and cracks in the structural elements. Plumb of the building was then measured, the results of which showed that there was negligible horizontal displacement in all directions. Concrete matrix and quality were also investigated in columns, beams, foundations and floors. Special attention was given to the crushed column by careful observation and testing from ground to the eleventh floor. It was discovered that the concrete in slabs, columns and in three exposed footings, was of good quality with sufficient strength varying from 27 N/mm² to 34 N/mm². However, at first floor level where the crushing of the column took place, the concrete was observed to contain more fines and had low strength of 19 N/mm². Therefore, it was concluded that the crushing of the column was due to the observed weakness, and it was recommended that the crushed column be strengthened by adding three columns attached to it, and all other columns from foundation level to the first floor be jacketed with 150 mm thick reinforced concrete membrane. Hence, a contractor was hired and carried out the strengthening work successfully. Finally, the City Authority permitted the residents of all four buildings to reoccupy again their dwelling apartments.

PO-35

Experimental Investigation of Creeping Effects Under Repeating Load Histories

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Certain concrete structures may be subjected to frequent but still longer-term loadings and unloadings induced by traffic (e.g. parking garages, city bridges, etc.) or other live loadings (e.g. storage buildings, offices, etc.). The intensity, duration and frequency of the variable loads can significantly influence the time-dependent behavior of concrete. Currently, these effects are considered in the codes through so-called quasi permanent load. However, the creep and recovery property under variable repeating loads are still far from clear.

First part of the study presents the main experimental findings about creep and creep recovery under various repeated load histories performed on a material level. Concrete specimens were exposed to frequently repeated loading and unloading cycles that produce different stress levels in concrete (0.30fc; 0.40fc; 0.45fc). The results indicate that regardless of the stress level, the creep becomes fully recoverable after a sufficient number of loading and unloading cycles.

Second part focuses on presenting the experimental program of an element-level tests in which full-scale reinforced concrete flexural beams will be exposed to comparable load scenarios. The load scenarios are designed based on the results from short-term pretests performed on identical beam elements. The final aim is to obtain the quasi-permanent coefficient for each considered load history, as well as to identify how it is influenced by different stress states of concrete.

PO-36

Performance of Geopolymers Doped with Antimicrobial Metal Agents under Aggressive Sewers Conditions

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Highly aggressive environmental conditions in wastewater infrastructure can lead to a fast rate of deterioration of concrete sewers. This degradation process is associated with complex biological activities referred to as microbial induced acid corrosion (MIAC). Damage related to MIAC is still an unresolved global challenge with high economic and social relevance. Currently used construction materials in sewers do not withstand long-term requirements, thus raising the demand for more durable alternatives. One option in this context is to reduce or totally inhibit relevant microbes from colonizing concrete surfaces in order to avoid in-situ biogenic sulfuric acid production. In this paper, we report results from an on-site testing campaign. Outsourced geopolymer mortars that have been doped with Cu and Zn metal ions in different concentrations are compared to geopolymer mortars without metal additions, calcium aluminate cement based mortars and OPC based mortars.

PO-37

Alternative alkali activators based on waste bottle glass and waste cathode-ray tube glass

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Alkali-activated binders are an environmentally friendly alternative to Portland cement, particularly when locally-available raw materials are used. It is well known that alkali activation with a sodium silicate activator generates a hardened binder with higher compressive strength than a binder hardened with sodium hydroxide. As the alkali-silicate activators are produced through energy extensive processes, and their use can significantly increase the carbon footprint of the final products, it is of great significance to develop alternative alkaline activators based on locally-available waste materials. This article assesses the potential to apply waste bottle glass and waste cathode-ray tube (CRT) glass to synthesise alternative alkali activators by the hydrothermal method. Inductively coupled plasma-optical emission spectrometry (ICP-OES) was used to determine silicon and aluminium content in the alternative activators. The influence of dissolution process parameters (time, temperature, particle size) on the concentrations of silicon and aluminium in the alternative activators was investigated. The alternative activators with silicon concentration up to 19 g/L and aluminium concentration up to 0.9 g/L were prepared at T = 120 °C and boiling time 24 h. The alternative alkali activators and, for comparison, also commercial sodium silicate were used in the alkali activation of fly ash powder. The formed pastes were cured at 70 °C for 72 h. Mechanical strength measurements indicated that alkali activation of fly ash with the optimal alternative activator yielded hardened paste with compressive strength of 33 MPa. However, the compressive strength of hardened paste prepared from fly ash and commercial sodium silicate reached 70 MPa. Part of this difference can be ascribed to the lower density of hardened pastes prepared with alternative activators.

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