



Central Europe towards
Sustainable Building
Prague | 2022 July 4–6

Book of Abstracts



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CESB22 conference is organized under the auspices of international conveners CIB, iiSBE, UNEP-SBCI, FIDIC and GABC, and belongs to the Sustainable Built Environment regional conference series leading towards the World Sustainable Built Environment conference on September 26–29, 2023 in Montreal, Canada.

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Book of Abstracts

Central Europe towards Sustainable Building 2022 (CESB22)

4th–6th July 2022, Prague, Czech Republic

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Foreword

Sustainability is about saving biodiversity on the Earth. Sustainability is about survival of humans on the Earth.

Humanity is currently faced to severe threats and distressing impacts. We are facing new experience how all the system is vulnerable and fragile, how all environment for the life of humans could be in extremely short time disrupted on global scale by decision of one person – energy system, food distribution, economy stability, safety, security, environment ... etc.

In October 2015 UN adopted resolution Transforming our World: the 2030 Agenda for Sustainable Development. This Agenda represents a plan of action in areas of critical importance for humanity and the planet. Buildings create environment for the life of people and thus represent key potential in fulfilling specified targets. The principal goal is to develop built environment to enable healthy, safe, and affordable high-quality life which will not harm the environment. New environmental, social and economic conditions require advanced technical solutions for construction as well as reconstruction and modernization of existing structures. Currently, an extremely important goal is recovery of damaged war areas into a new sustainable and resilient built environment.

These goals, targets and proposed solutions should be widely discussed in international group of experts, considering global measure of the problem and consequently regionally specific situation. The conference Central Europe towards Sustainable Building 2022 is platform for exchange of ideas and can contribute to intensive search for plausible solutions.

The conference CESB22 is a part of SBE series of conferences organized under auspices of iiSBE, CIB, UNEP, SBCI and FIDIC in various regions of the world. CESB22 continues the tradition of sustainable building conferences in the Central Europe. The organizational team has already organized five international CESB conferences, in 2007, 2010, 2013, 2016 and 2019.

The main conference topics are:

- Innovative technologies and systems
- New materials and components for sustainable buildings
- Energy efficient buildings and districts
- Adapting design, construction and operation of buildings to climatic goals
- Integration of principles of circular economy into building design process

- Decision-support tools and assessment methods for sustainable built environment
- Retrofitting of existing building stock
- Sustainable refurbishment of cultural and industrial heritage
- Improving resilience of the built environment
- Sustainable urban development

YRSB – Young research sustainable building forum – a conference for young researchers, especially doctoral students is traditionally organized in parallel with CESB22 conference.

We would like to express our thanks to all authors for presentation of their achievements and sharing their ideas within our community. All abstracts and papers were carefully blind reviewed thanks to active participation of members of the Scientific Committee.

We also thank to the Czech Technical University in Prague, Faculty of Civil Engineering and University Centre for Energy Efficient Buildings and international conveners iiSBE, UNEP, CIB and FIDIC for their kind support. We thank also to all supporting organizations that provided their auspices, to our media partners who helped us to spread the word and last but not least to our commercial partners and exhibitors.

A special thanks are addressed all members of organizing committee especially Alena Bílková, Kateřina Sojková, Martin Volf, Julie Železná, Magdaléna Novotná, Jakub Diviš, Petr Hejtmánek, Jana Hořická, Tereza Pavlů, Nika Trubina, Jenna Carlet for their continued efforts in organizing this event. All help and support were needed for successful organization of the conference and all satellite events. Without help and kind support of all these people and organizations the CESB22 conference would not be possible.

We hope that conference CESB22 will contribute to enhancement of knowledge in the field of sustainable buildings and built environment considering changing natural, as well as socio-economic situation in the world.

In Prague in June 2022

Petr Hájek
Jan Tywoniak
Antonín Lupíšek

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Keynote Addresses

The buried giant: construction materials shape the environmental footprint of buildings

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Abstract: The environmental impacts, including those related to greenhouse gas emissions, of the construction and deconstruction of buildings come more and more into focus of governments and professional building owners. In new constructions these so-called embodied impacts are often more important than the environmental impacts during 50 years use phase. How did the environmental impacts caused by construction materials and building technologies and their supply chains change during the past three decades? What might be expected in the future? How did LCA contribute to the past development and how did LCA practice evolve during this period? Finally, are current LCA practices suited to support the transformation of the building stock towards net zero greenhouse gas emissions?

In a first part, the past as well as the potential future development of the environmental impacts caused by the manufacture of selected key construction materials and their supply chains will be presented. The main measures which lead to lower impacts in the past and which will be needed to further reduce environmental impacts in the future will be named. Current trends will be assessed against their effectiveness to reach net zero greenhouse gas emissions of buildings and the built environment.

In a second part the history and evolution of LCI data collection and data management will be discussed. Several aspects will be covered such as information sources, modelling and methodology, environmental impacts (pollutants and resources) covered in the LCIs, IT resources and solutions, and information policies.

A fossil free future – scenarios for Austria – implications for Europe

Wolfgang Streicher

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Abstract: If the energy transition completely away from fossil fuels to renewable energies due to climate change and to reduce the dependency from not or semi democratic countries is taken serious, many implications and needed measures have to be faced. In the keynote a general approach with the options reduction of energy demand, generation of renewables within the countries and, if not enough renewable energy is available locally, where could the additional renewable energy be imported from, will be shown. Additionally, the question of energy storage is tackled to overcome the timely variation of the production of renewable energy carriers and the demand. The whole process is shown in detail for the province of Tyrol/Austria, where the possible potential of renewables is compared to the energy need after possible reduction of the energy demand in the whole energy system. The sectors housing, mobility/transportation and industry are included. It will be shown, that the energy efficiency of the whole system needs to be as high as possible and that not only technologic measures are needed but also many other aspects like laws, democracy, micro- and macroeconomics etc. have to be looked at and several dilemmas have to be solved. Concerning the cost it has to be stated that no transition if the energy system will become far more expensive due to the costs of climate change compared to the costs for the energy change, which ranges in about 1 %/GNP.

Making our Industrial Heritage work for the future, in the context of climate change

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Abstract: As Climate Change continues to drive major changes in policy and practice on a global scale, the role of industrial heritage is becoming increasingly important. There remains strong pressure from business interests to clear away the past and start again from a blank canvas, but now there are growing arguments for an alternative approach which re-cycles the carbon already invested in industrial buildings and structures and gives them a second life. There is also an increasing number of examples that demonstrate the power of industrial heritage to drive sustainable regeneration and re-vitalization schemes across the world. Significantly, this trend is not confined to the most attractive, aesthetically pleasing structures – a wide variety of industrial sites have been imaginatively adapted to a new life and in many cases have helped engineer a vibrant future for previously marginalised communities and areas.

In Scotland, our national heritage body, Historic Environment Scotland, recently published its 'Climate Action Strategy'. At its heart is the ambition to transform the challenge facing us from one in which our heritage is a victim, instead harnessing it and all its attributes in the battle against Climate Change. This paper will argue that industrial heritage is especially well placed to do this.

Keywords: Industrial; Heritage; Sustainability

Solar Decathlon Europe 21/22 – Experiences and Findings

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Abstract: The Solar Decathlon is a competition for universities from all over the world to design, build and operate small experimental solar powered houses. Its first edition took place in the US in 2002. Since 2010 it is in practice in Europe with four competitions and 65 net zero or net energy plus houses build and tested in 10 disciplines (decathlon). The lecture provides an overview and initial experience and findings from the 22nd edition of the competition in Wuppertal, Germany. It represents a profiling on densification in the existing urban environmental, resource efficiency and carbon neutral energy supply towards climate neutrality.

Tools for Building Design

Toward a critical assessment of indoor environmental quality standards

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Abstract: Building design and operation requirements regarding indoor-environmental quality (IEQ) are of direct relevance to occupants' needs. In most buildings, occupant-related requirements pertain to the provision of conditions that support optimal task performance and are subjectively perceived as comfortable or pleasant. Codes, standards, and guidelines that specify IEQ requirements are commonly viewed as the main sources of reference for practitioners, who are expected to follow the provisions in these documents and provide corresponding proof of compliance. However, actual code compliance processes are not always accompanied by critical reflections regarding the evidentiary basis of the entailed mandates and recommendations. It is thus necessary to critically scrutinise standards in view of explicit or implicit references to the scientific basis of the entailed mandates. The present contribution explores and details a path toward such a critical assessment. To this end, we considered a number of typical and frequently referenced standards pertaining to thermal, visual, and air quality aspects of indoor environments. The results of this illustrative assessment effort highlight the scope and limitations of the standards' default approaches to the definition of IEQ-relevant requirements. Moreover, they point to considerable gaps in the chain of evidence from standards' immediate content to the underlying factual sources.

Keywords: Indoor environmental quality, standards, evidence

Sustainability Aspects in Real Estate Management – Basics and Opportunities for an Indicator-Based Target and Reporting System in Real Estate Companies

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Abstract: Real estate companies face manifold challenges and tasks when it comes to the implementation of sustainability principles. Respective principles refer to sustainability aspects in the design, construction, operation & maintenance and deconstruction phase of single-buildings as well as to the ensuring of future proofness in the whole institutional building stock. Moreover, companies must realign their corporate strategy and rethink their sustainability reporting conventions in order to fulfil legal requirements and to stay competitive. For all the various tasks indicators can help to manifest goals on specific decision levels of Real Estate Management (REM) while they also play a relevant role in sustainability reporting and assessment. The question arises if and to which extent synergies exist in the gathering of information as well as in the development, use and interpretation of indicators for the different tasks in REM. This contribution presents a system of information flows that is able to support a horizontal and vertical integration of information and that takes in count system boundaries and reference units to illustrate the characteristics of specific action and decision levels. Results from a research that reflects the situation in Germany and considers current developments in the EU will be presented.

Keywords: Sustainability Indicators, Key Performance Indicators, Sustainability Assessment, Corporate Sustainability Reporting, Information Management, Portfolio Management

Environmental performances evaluation through building information models

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Abstract: The construction industry produces several negative environmental impacts. To promote solutions that reduce these negative impacts, it is crucial to increase awareness among all parties involved in the supply chain. Currently, certification protocols, environmental labels and declarations are the most common tools for promoting sustainability in the construction industry. However, these tools are generally non-mandatory and require specific competencies to thoroughly understand and interpret their outputs, especially for non-specialized users in sustainability assessment. This paper presents a tool for visualizing environmental impacts directly through a Building Information Model, by assigning different colours to model objects according to their environmental performances. Understanding environmental performances data is thus more accessible to non-expert users. Unlike several BIM-LCA integration studies that primarily focus on the needs of designers, this contribution considers the perspective of manufacturers. The developed tool focuses on building products and has been carried out with the Autodesk Revit BIM authoring platform and its VPL-based Dynamo plug-in. Through the combination of 3D models and histograms, the tool facilitates manufacturers to visualize with real-time updates which phase of a product life cycle requires sustainable innovation, which sub-components or process determine the major environmental impacts and calculate the environmental cost indicator of a product.

Keywords: BIM (Building Information Modeling); sustainability; environmental impacts; LCA (Life Cycle Assessment); ECI (Environmental Cost Indicator)

Reuse of waste heat from IT equipment

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Abstract: There is a large potential in energy savings in regard to reusing waste heat from IT equipment. In the study, a calculation on waste heat recovery from a virtual data center has been evaluated on a specific residential building. The data center has been designed based on knowledge gained from personal in-situ data gathering as well as on the authors studying the given issue.

Keywords: Data centers, heating and domestic hot water, IT equipment, waste heat

Quantifying the Impact of External and Internal Factors and Their Interactions on Thermal Load Behaviour of a Building

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Abstract: For the energy-efficient design of district heating networks, knowledge about the neighborhood heat load behavior, through heating load profiles in high temporal and spatial resolution, is crucial. Due to the high effort required for transient calculations, a less complex method is needed at the neighborhood level. For this reason, a method is developed, which identifies the relevant parameters influencing the building heating load behavior. Taking these parameters into account, a simple method for heating load profiling is developed using a machine learning algorithm. For this purpose, a parameter study is conducted using dynamic thermal building simulation software. Different parameters influencing the building heating load behavior are varied. To determine the strength of the influence of the individual parameters on the building heating load, to check whether the influence of the parameters is constant or varies over the year and whether parameters are missing here, the results of the parameter study are evaluated statistically. First results show promising results in the detection of the significant parameters, for the creation of a model based on a machine learning algorithm, and the possibility of quantifying their impact on building heating load behaviour

Keywords: Energy-efficient building design, sector coupling, thermal load behaviour, standardised and parameterised thermal load curves

Options of Modelling Refurbishment in LCA: Continuous Improvement Strategy and Next Life Cycle Approach

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Abstract: Compared to other goods, buildings have a long lifespan. It is therefore the norm and not the exception that adaptation will be needed at some point in their life cycle to changing environmental conditions, technical progress and new/ additional user requirements. The adaptation of existing buildings to future challenges in the form of refurbishment contributes to sustainable development. The proportion of refurbishments is increasing in both absolute and relative terms in the building sector in Europe. It is therefore surprising that the modelling particularities of refurbishment in the context of a life cycle-based environmental performance assessment are still neglected in the EN-standards. The paper deals with these particularities. Specifically, it presents a typology of approaches starting with a distinction between planned refurbishment as B5 and unforeseen refurbishment as an independent design and construction task/ next life cycle, as well as the status of the discussion in selected countries. Recommendations for action for the life cycle assessment are given for specific decision-making situations.

Keywords: sustainable development, buildings, refurbishment, re-purposing, life cycle assessment

Review of sunlight exposure of buildings in Central Europe climatic conditions

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Abstract: The sunlight exposure represents one of key parameters of indoor climate comfort. The evaluation of sunlight access into buildings is based on a methodology of European standard EN 17037. The methodology is focused on specification of an insolation time which would comply with requirements for the sunlight exposure of permanently occupied spaces like houses and residential buildings as well as schools or hospitals. The sunlight exposure evaluation is recommended to be between 1st February and 21st March. The specific date from the interval can be selected for individual evaluations. This is a relatively long period of days in which the insolation could vary meaningfully.

The aim of this study is to evaluate how the sunlight exposure might be changed in the recommended standard period in dependence on the geographic locality and climatic conditions in the Central Europe region. It depends on the sunlight time and specific design situations as well as shading obstructions. The review of the sunlight exposure is determined. The review results can perform information about design possibilities for the sunlight exposure in real buildings in the given climatic locality.

Keywords: solar radiation, sunlight exposure, solar altitude, building insolation

Applying life cycle assessment with minimal information to support early-stage material selection

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Abstract: Traditional life cycle assessment (LCA) is too data intensive and time consuming to be used during typical building design processes. Conducting an LCA during the building design process therefore requires simplifications and assumptions. Such ‘screening LCAs’ are quicker and can be used with less data but introduce greater uncertainty. Unfortunately, uncertainty is not reflected in standard deterministic LCA calculations, which produce single-point values in LCA results. Thus, in this study, data quality scoring has been incorporated into a screening LCA to produce probabilistic predictions of environmental performance based on limited data. The approach has been applied during the design process of a bio-based wall panel designed for a circular economy. A combination of ecoinvent and material data sheets were used to analyse a wide range of novel bio-based insulation materials. The screening LCA analysed global warming potential and identified a short-list of promising materials that were then subjected to a detailed LCA for further consideration in the design. The method uses publicly available information and can be applied at material or building-element level. The method thus helps designers estimate environmental impacts without hindering the design process.

Keywords: Life Cycle Assessment, Bio-based Materials, Circular Economy, Uncertainty

Toolkit for the efficient articulation of sustainable strategies with design and management methodology used by AECO industry in Latin America

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Abstract: Digital transformation is changing the world, and with it the construction and architecture industry, however, although there are many collaborative work frameworks for digitization, and agile philosophies among different professionals, the methodologies of creative processes throughout the entire life cycle of a project that involves sustainability strategies have been greatly reduced and relegated over time. Latin America has the highest levels of biodiversity, a wide variety of climates, a range of implementations and sustainable opportunities that have been sidelined versus the speed of innovation in construction projects, in this context, the design philosophy based on nature must be implemented as a premise from leaders to developers, regardless of the management method used. This document studies the sustainable construction progress in five Latin American countries, analyzing climatic, regulatory and socioeconomic aspects, with the aim of increasing processes efficiency towards better sustainable constructions. Consequently, it proposes a methodology for the creation of an effective sustainable tool which works hand in hand with information systems and synchronous digital collaboration (BIM, VCD or IPD), in order to improve the design and management of sustainable projects throughout their life cycle through specific design strategies and design guidelines for each city, using the cities of Buenos Aires, Brasilia, Santiago, Bogotá and Lima as a case study.

Keywords: Sustainable design, digital transformation, AECO, design and management methodologies, efficiency, Building Information Management, sustainable certifications.

Towards an automated and objective assessment of data from visual inspections of building envelopes

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Abstract: The renovation planning process is filled with uncertainties and subjective decisions. These make the decisions upon what and when to renovate a complex and ambiguous problem. Selection of renovation measures related to building envelope are often far from optimal as decisions are usually made based on visual inspections. These are manned and thus prone to subjective assessment and the know-how of individual inspectors. Furthermore, objective criteria which could indicate non-structural failures are often missing. The objective based planning process allowing the estimation of the current damage status of the building envelope by only using non-destructive measurements is still in its infancy. The first step requires establishing reliable and objective based data collection. These could be efficiently collected by Unmanned Aerial Vehicles (UAV) with subsequent image recognition algorithms allowing the identification of imperfections and store the position and extent of such deviations into the building's digital assessment database. Such tools do not exist. The aim of this study is to investigate the current objectivization possibilities in the domain of building inspections. The first part provides a literature review describing how an autonomous UAV survey of a building envelope may be planned and what computer vision techniques may be used for automatic damage recognition and classification. Subsequently, an objective detection model based on the YOLO-tiny (You Only Look Once) computer vision framework is employed in a case study investigating a building envelope of historical Tjolöholm castle in Sweden. This study contributes to developing a methodology for an objective based visual inspection process.

Keywords: UAV, computer vision, object detection, YOLO, case study, building, renovation, brick, masonry

Lightwell in residential building: architectural solutions to the daylighting performance through parametric simulation

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Abstract: The lightwell is an architectural solution to promote daylight into the internal spaces from the core of a building. The shaft configurations, such as geometry and reflectance can affect the performance of the daylighting entering the adjoining rooms under different conditions. This study aims to indicate the adequate architectural solutions to improve the daylighting performance of buildings with lightwells at three different southern latitudes. From a base model of 6-stories building, alternative cases were parametrically simulated using Rhinoceros, Grass-Hopper and ClimateStudio software. From variations in the lightwell geometry and walls reflectance, the cases were analyzed considering the lighting metrics UDI and sDA300. Results demonstrate that the daylighting is adequate on the floors near the top of the building and weakens towards the base of it. In Macapá, São Paulo and Chile, the sDA values reach 100% on the top floor, but only 3% on the first floor. It was also observed that materials with high diffuse reflectance on the shaft is more efficient in improving the daylighting performance than increasing its geometry. This research presents early-design guidance to inform architects and policymakers when considering the exploitation of daylight by the use of the lightwell.

Keywords: Lightwell. Daylighting. Wall Reflectance. Built Environment. Parametric Simulations

Attitude Towards LCA in Hungary and Czechia – Results of a Survey among Building Design Professionals

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Abstract: Architects and designers have a critical role in promoting Life Cycle Assessment (LCA), a scientific methodology for evaluating the environmental impacts of buildings that can help decarbonise the built environment and minimise other negative effects.

This paper presents the results of an international survey conducted among design professionals as part of the IEA Annex 72 project about assessing life cycle related environmental impacts caused by buildings. Twenty-three countries were participating in the survey altogether, but in this paper, only the specific situation in two Central European countries, Hungary and Czechia, are presented. The questionnaire explored the designers' understanding of environmental problems and LCA methodology, the drivers and barriers of environmental assessment and the future perspectives.

The results show that many architects and designers are concerned about environmental problems and the built environment's contribution but have a limited understanding of the applicable scientific methods. A full LCA is seldomly applied as neither regulations nor clients demand it, and only the operational energy is mandatorily assessed. Further improvements in data quality and assessment tools and regulatory and other drivers are needed to increase the use of LCA in the construction sector.

Keywords: survey, life cycle assessment, building design, architecture

Comparison of Thermal Bridge Calculation Methods

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Abstract: We need to consider linear heat losses due to thermal bridges for the accurate calculation of building heat losses. Our research examined a whole building, and different thermal bridge calculation methods were compared. The following techniques were included in the study: a simplified method according to the Hungarian energy performance regulation where the effect of thermal bridges can be taken into account by multiplication factors applicable to thermal transmittances; a simplified thermal bridge catalogue of ISO 14683; a recent national thermal bridge catalogue; two-dimensional thermal modelling as well as a conjugated heat and moisture (HAM) simulation considering steady-state and dynamic conditions. Overall, we created eight different numerical modelling approaches depending on the type of simulation and boundary condition. The modelling and simulations were carried out using multiphysics software based on the finite element method according to ISO 10211 and EN 15026. All the relevant details of the building were analysed to get a complete picture. Based on the results, we analysed each method's relative proportions of surface and linear heat losses. The evaluation showed that the Hungarian simplified method generated the lowest heat losses for thermal bridges, while ISO 14683 produced the highest results, with the numerically simulated results in the middle. The overall heat losses varied by 30%, depending on the thermal bridge calculation method. Linear heat losses were between 12% to 32% of the surface heat losses. Our study helps to choose the adequate method to perform thermal bridge simulations.

Keywords: thermal bridges, building constructions, heat and moisture transfer, numerical modelling

Development of scientific requirements for climate-neutral buildings and sustainable funding schemes in Germany

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Abstract: The German Climate Protection Plan 2050 describes interim targets and measures for the implementation of the Paris Climate Agreement, including the building sector. With the “New European Bauhaus”, the EU Commission has currently initiated an ambitious process. While new construction has been in the foreground up to now, the existing building stock must make a significant contribution to achieving the climate protection goals in the future. Robust building technology and a high degree of adaptability lead to a longer useful life and are thus more sustainable, both economically and in terms of ecological balance. Resilience to the consequences of climate change is gaining in importance.

The main goal of this contribution is to inform about the latest developments in governmental policies and subsidy schemes. As part of the National Climate Protection Programme 2030, the new “Federal Funding for Efficient Buildings (BEG)” was introduced in 2021. Research projects investigated how, with the introduction of efficiency house classes, funding can take greater account of the life cycle approach and other aspects of sustainability. At the same time, general and special requirements for the ecological, socio-cultural and economic quality were developed as a supplement to the existing certification systems and introduced by the Federal Building Ministry as “Quality Seal for Sustainable Buildings” (QNG).

Keywords: Sustainable Building, New European Bauhaus, Sustainability Assessment, Climate Protection Plan, Federal Funding

Energy Performance Estimation for Large Building Portfolios with Machine Learning-Based Techniques

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Abstract: Building operation is responsible for 28 % of the world's carbon emissions. In this context, establishing priorities in refurbishment strategies at the scale of a city or a group of buildings is important. Such procedures are usually led by experts in energy performance and, therefore, they are rarely carried out due to their long and costly nature.

This research aims at the estimation of building energy performance to pave the way towards finding near-optimal refurbishment strategies. Thanks to the identification of easily-accessible building characteristics, the method applies machine learning models to scan a building portfolio based on a low level of details. The results show good potential to identify low-performer buildings with simple machine learning methods. It also opens the door for further improvements through the inclusion of supplementary building features at the input of the predictive system. This work includes (a) the integration of a knowledge database thanks to the Swiss CECB energy performance certificates, referencing more than 70'000 buildings, (b) the preparation of a training data set through the selection of relevant physical characteristics of buildings (input) and the corresponding energy consumption labels (output), (c) the development of predictive models used in a supervised way, (d) their evaluation on an independent test set.

Keywords: refurbishment strategies, machine learning, energy performance certificates

Decision-support tool for prioritizing retrofitting actions on Social Housing stock in Italy

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Abstract: Housing is the main environmental impact generator (62%) of the whole building sector, but it also has the greatest reduction potential. Enhancing its performance is thus crucial to sustainable development. Social Housing [SH] represents a critical asset within the residential segment, due to the recurrent investment shortage and several environmental, social, and economic related implications. In Italy, SH is held by around one hundred public agencies facing endemic resource constraints for both maintenance and retrofitting, which are limited further by a diffused lack of information regarding the conditions and features of the buildings they manage. In cooperation with an Italian SH agency (ACER Bologna), we developed a speedy tool to compare the technical and economic effects of different refurbishment scenarios on a case-by-case basis. This is not a tool to manage retrofitting works, as the many already available, but a means to help large housing managers overcome the intention-action gap that limit their capacity to properly prioritize interventions based on reliable information. The research focuses on the validation of the fast procedure for estimating the baseline energy scenario, arguing that the relatively small inaccuracies are irrelevant for the scope of the tool and are compensated for by the time saved.

Keywords: retrofitting; social housing; decision-support tool; energy efficiency

Reliability Approaches Affecting Sustainability of Existing Steel Structures

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Abstract: Steel structures are second most numerous in the stock of existing buildings. In contrast to dominating concrete buildings, they are typically lightweight and are more sensitive to alterations in use or loads. While the sustainability principles require to maintain and keep using these structures, structural assessments often indicate insufficient reliability and need for replacements. The submitted contribution shows that the most important reliability considerations affecting the sustainability of existing steel structures consist of specifying (1) appropriate target reliability level, (2) verification methods, and (3) intervention procedures. The study focuses on the first two aspects. (1) Optimum target reliability can be specified by probabilistic optimisation considering sustainability aspects including structural costs, and expected consequences of replacement and of possible failure. It is shown that lower reliability levels might be considered for the assessment of existing structures than for the design of new structures, with benefits for sustainability in construction.

Regarding (2), the most efficient verification methods are based on advanced probabilistic approaches. It is demonstrated that sustainability may be significantly affected by the selection of assessment methods. Advanced reliability approaches commonly reduce assessment requirements by 10–15%. Sustainability indicators are mostly related to the key aspects (1) and (2). Using the advanced methods may bring a significantly positive contribution to sustainability, particularly when an upgrade of the existing structure is associated with high economic cost and significant environmental impact.

Keywords: Existing structures, adjusted partial factors, probabilistic approaches, reliability

Thoughts on the selection of the appropriate simulation models in building performance assessment

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Abstract: Building performance simulation serves the derivation of the relevant building performance indicators (e.g., energy use, indoor-environmental conditions) given the assumptions of certain model input parameters (i.e., description of the building, boundary conditions, occupants' presence and behaviour). Simulation can be employed for multiple purposes, including but not limited to building design support, building systems configuration, and code compliance demonstration. It has been suggested that the level of detail and resolution of simulation models must match their deployment purpose. However, there is arguably a lack of definitive guidelines for the purpose-dependent selection of appropriate simulation models. To address this challenge, the present contribution suggests that the attributes of a simulation model in general, and the type of the adopted occupant model in particular, must correspond to the specifics of the building performance indicator under investigation. To make progress in this area, a typological classification of building performance indicators is proposed along three salient dimensions, namely the indicators' topical domain (e.g., energy use, thermal comfort, noise control), their spatial attributes, and their temporal attributes. Following a detailed analysis, the paper presents a high-level approach to derive the basic requirements concerning occupant models as a categorical function of the simulation purpose.

Keywords: Building performance, simulation purpose, model selection

Integrated sustainability assessment using BIM

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Abstract: The construction industry is responsible for 40% of the energy consumption and 36% of the CO₂ emissions, and buildings are responsible for a significant part of energy consumption in Europe.

Thus, a growing concern regarding environmental impacts in the construction sector is in place. Reducing these impacts and optimise the design process is a major priority, and technology needs to be integrated along with the design to allow for better buildings performance. Building Information Modelling (BIM) methodology is one of the technologies that is revolutionising how the supply chain delivers the construction projects, allowing for an overview of the whole life cycle, keeping track of the data along the process, and potentiating more advanced simulations and supported decisions.

The tool proposed in this paper aims to integrate different types of sustainability analysis, namely Streamlined Life Cycle Assessment (LCA), Carbon Footprint, Life Cycle Cost (LCC) and Level(s) framework with BIM. This involves defining adequate Product Data Templates (PDT) and a database structure for BIM objects, including the necessary parameters to enable designers to do holistic and dynamic assessments from early design stages to a complete LCA. Also, considering the importance of using BIM to visualise different scenarios, a graphical interface will be developed to show the key sustainability indicators and support decision-making for more sustainable buildings. The results achieved show that technology must be taken to meet Climate most ambition targets and reduce the impact of construction.

Keywords: Building Information Modelling, Sustainability, Technology, Life Cycle Assessment, Life Cycle Cost

Connected design decision networks: multidisciplinary decision support for early building design LCA

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Abstract:

Life Cycle Assessment (LCA) has become the standard method to evaluate environmental impact throughout the life cycle of buildings. However, detailed data about the future building as well as knowledge about the mutual influence of decisions concerning the various disciplines involved are often missing in early design phases, otherwise known to bear the highest potential for emissions savings. Hence, a meaningful basis for decision making is lacking.

This study suggests a method to digitally represent decisions and their interdependencies in early design phases and visualize their possible consequences for the life cycle of the future building. The method is based on identification of relevant processes and tasks concerning architecture and Heating Ventilation and Air Conditioning (HVAC). Decisions trees of these tasks are used as a point of departure. Connecting the decision trees to a multidimensional, Connected Design Decision Network (CDDN) enables an interdisciplinary design team to pinpoint strategic decision nodes with comparatively more interdependencies with other subsets and high influence on LCA results. We believe that a transparent decision making in early design stages can be valuable to both the design team as well as clients and contractors and bear potential for an increased mutual awareness minimizing late and expensive redesigns.

Keywords: LCA, integrated design process, Multi-Criteria Decision Making (MCDM), early design phase, interdisciplinary decision network

European Environmental Databases. OpenDAP, Spanish context

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Abstract: With the aim of facilitating sustainability assessment through Life Cycle Assessment, the Eduardo Torroja Institute of Construction Sciences. CSIC is developing a public database of environmental information: OpenDAP. One of the objectives of this database is to be compatible with other European databases but to be fully open, public and free of charge. With the participation in the project “Wood for Sustainable Construction Task Force”, whose coordinator was the University of Cordoba, 10 EPDs have been developed for different wood products and species, with a detailed study of each stage, using a spreadsheet and field studies for data collection.

In this article we aim to demonstrate the need for environmental quantification of services and products in the construction sector, due to the importance of the global impact of this sector. With common procedures that allow us to obtain comparable and useful results for the final client who selects them. Both for generic and specific products, being stable and exportable. Allowing us to compare, reduce and improve our sustainability.

Keywords: LCA, Databases, EPD, OpenDAP, environment

Review and analysis of existing methods to assess the Indoor Environmental Quality (IEQ) for office buildings

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Abstract: Population in developed countries spend most of their time indoors, whether in their homes, workplaces, stores or leisure areas. Due to the COVID-19 pandemic, this situation worsened and now, more than ever, the importance of a high Indoor Environmental Quality (IEQ) is highlighted. The IEQ is very important in building performance since it is directly related to its occupants' comfort, health, wellbeing, and productivity and the Sick Building Syndrome (SBS) concept. Therefore, it is essential to develop tools to support designers' decision-making in the materialization of indoor environments with higher quality. From the state-of-art analysis, it is possible to conclude that the methods to assess the overall building performance already consider the IEQ. Still, most use an approach that does not cover all relevant indicators.

In this context, this paper presents the first milestone of a research work that aims to develop a new method to rate the overall IEQ of office buildings in Portugal.

The main objective of the present study is to propose a list of IEQ indicators for office buildings, adapted to the Portuguese context, based on the analysis of existing rating methods for buildings and the recommendations of national and international standards.

Keywords: Indoor Environmental Quality (IEQ) indicators, decision-support tools, office buildings

Tools for Urban Development

Supporting sustainable policies through an Urban Energy-Environmental Model and a Multi-Criteria Analysis: a case study in an Italian province

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Abstract: Public Authorities (PAs) need to define cross-cutting strategies for urban planning including policies for sustainable and energy-efficient buildings and innovative urban solutions. The article presents a decision support tool that combines an Urban Energy Environmental Model (UEEM) and a Multi-Criteria Analysis (MCA) to support the development of sustainable local policies. The UEEM, developed with a bottom-up approach incorporating energy and environmental items, provides a representation of the performance of local urban areas and quantifies the impact of new interventions in expansion areas. The UEEM is based on the definition of virtual archetypes built on the characteristics of the area under consideration. 92 building archetypes and 40 urban archetypes are developed. The energy performance of each building archetype is calculated with a dynamic simulation tool. The environmental performance of urban areas (overheating risk and outdoor thermal comfort) is analysed through a Grasshopper-based parametric model. In addition, soil permeability is calculated. The UEEM results are aggregated into a single index using the MCA, providing a Municipal Rating Index (MRI). The weights of the MCA are estimated through the Analytical Hierarchy Process (AHP) based on a survey submitted to local stakeholders (municipalities, environmental associations, experts). The model is applied to the province of Monza and Brianza in northern Italy.

Keywords: urban planning, urban energy environmental model, multi-criteria analysis, analytical hierarchical process

A Theoretical Assessment of Transport Emissions from Institutional Buildings in Norwegian Municipality

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Abstract: Municipalities are key actors for reaching the sustainable development goals 9, 11, 12, 13 set by the United Nations. This paper aims to develop a theoretical framework that will aid municipalities in managing their building stock more sustainability. The framework focuses on reducing embodied and operational emissions, including travel-induced emissions. The focal point in this paper is institutional buildings governed by a Norwegian municipality as they are the daily destination for many inhabitants. An existing framework in the municipality value the building stock based on quality and the cost of refurbishing them. No framework is currently including travel-induced emissions in the evaluation.

The intention is to provide a holistic framework that includes this aspect when deciding if a building should be refurbished or demolished. The omission of transport emissions can lead to truncation errors in assessments. The transport to and from the school generates higher emissions in certain scenarios. Based on the knowledge in the assessment a theoretical framework that assesses this is developed.

Keywords: CO₂ abatement, travel-induced emissions, location, institutional buildings, municipality

Holistic Assessment Methodology For Positive Energy Districts

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Abstract: Globally, cities are responsible for most of the world's energy consumption and most of the carbon dioxide emissions. Therefore, the efficient transformation of urban energy systems is becoming a crucial step towards carbon neutrality and more effective climate protection. The Positive Energy District (PED) concept has been pointed out as one of the key principles of this path. The Positive Energy District concept leads towards an integrated and sustainable urban development with an emphasis on the use of renewable energy sources and attention shifting from energy performance at the level of individual buildings to the level of the entire district. However, PEDs represent a relatively new and still not sufficiently explored area in the field of sustainable development.

The aim of this paper is to describe a new holistic assessment and innovative process of stakeholder engagement to identify Positive Energy Districts in the early development phase that arises within the PED-ID project. The early development phase is crucial since the structure of the urban area is being decided along with its sustainability and climate protection levels.

The assessment methodology is based on the creation and optimization of energy balance scenarios.

Case studies of existing urban areas have been developed in order to verify the methodology.

It is concluded that this innovative methodology devised for PED evaluation, together with strengthening of knowledge-based and decision-making framework, will help to accelerate the process of transforming the current urban energy systems into more efficient and renewable systems.

Keywords: Positive Energy Districts, Sustainable urban development, Assessment methods

Exploring machine learning-based archetypes for urban life cycle modeling (UBiM)

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Abstract: Urban analyses demand simplifications that balance modelling level of detail and scope broadness. Thus, classification by archetypes is a promising methodological approach. Such an approach is common for energy studies but rarely applied for Life Cycle Assessment (LCA) purposes. When archetypes are used in urban LCA, they generally result from previous studies for classification and characterization according to parameters that directly affect the operational energy performance of buildings. This paper tackles two research questions: i) Is it appropriate to aggregate building stocks based on operational energy (OE) variables when life cycle impacts are investigated? ii) When integrated LCA (OE + embodied impacts) is pursued, would variables describing both interests simultaneously result in better representation than using operational energy-based clustering to predict embodied impacts and vice versa? Thus, we aim to confirm that, combining variables that govern OE and embodied impacts offers a better result than using OE to predict materials groupings, even if some adherence is lost relatively to single-objective clustering. Clustering experiments were carried out for the campus of the University of Campinas, Brazil. After unsupervised k-medoid (PAM) grouping, the data were submitted to a supervised learning (neural networks) classification method. Generated confusion matrices demonstrate how adherent the clustering is when considering one interest to predict the other in three situations. Results indicate that an operational energy-driven archetype fails to represent buildings from the embodied impacts viewpoint, and that merging operational energy and embodied impact variables would better support integrated life cycle impact predictions.

Keywords: Archetypes, Building stock aggregation, Clustering, LCA, life cycle impacts, urban modelling

Proof of Concept - Using Prospective Hybrid MFA-LCA to Evaluate the Environmental Implications of Circular Economy using a case study of Wood

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Abstract: Consistent evaluations of impacts induced by implementation of Circular Economy (CE) design processes and solutions within the built environment, necessitates decision-support tool development/advancement, as CE does not allow for business-as-usual assessments only. A preliminary test of concept that seeks to quantify the environmental implications of CE on a case study of wood, is presented here.

The core methodology is based on coupling of the Shared Socioeconomic Pathways (SSPs) with Material Flow Analysis (MFA) and consequential Life Cycle Assessment (cLCA). Applying this novel approach, a prospective consequential hybrid MFA-LCA analysis was initiated, to evaluate the mitigation challenges of CE design processes, through different formalized and generally accepted (i.e. consensus) scenarios.

The case study is based on Danish reference buildings, meeting the current building regulations, designed to replace conventional building materials with wood. This ‘wood-approach’ for test of concept case study, is chosen due to the increasing interest in wood construction.

The development and calibration of a prospective model for different building material consumptions will further illuminate the connection between the to-be generated emissions and the marginal productions of the materials in question, under specific sets of societal development scenarios.

Keywords: Hybrid MFA-LCA, Consequential LCA, Circular Economy, Shared Socioeconomic Pathways (SSPs)

Digitalising cities: A methodology to map evaluation requirements into robust and feasible data collection approaches

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Abstract: The sustainable development of cities relies on the implementation of multi-sectoral actions towards carbon neutrality, reducing the air pollutants emissions. The actions' decision-making process for cities transformation should be supported by lessons learnt from previous interventions and KPIs (Key Performance Indicators). To do so, gathering real data becomes pivotal, complementing simulation tools (currently used), solving the inherent uncertainties due to assumptions. Data collection methodologies are then necessary, being the main driver for digital cities and providing better mechanisms for informed decision-making. Most of the cities still operate in silos and do not always implement the strategic plans supported with a digitalization of the municipal processes. Within this perspective, this paper presents a methodology to support cities in the preparation of monitoring programmes to collect real data in a robust and feasible manner. Taking the KPIs and the Smart Cities urban strategies into account, this paper concludes with some lessons learnt within cities to deploy monitoring approaches. From the city challenges to the review of the plans, all the process is driven by real data and KPIs. The methodology has been applied in the mySMARTLife project (Grant Agreement #731297) and deployed into the cities of Nantes (France), Hamburg (Germany) and Helsinki (Finland).

Keywords: digitalisation, sustainable cities, KPIs-based assessment, monitoring, decision-making, data

New Materials and Components for Sustainable Buildings

Structural Optimisation of a Façade Fastening System with the Target Function of Minimising Thermal Conductivity

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Abstract: Affecting a building's energy efficiency, façade constructions play a decisive role. Among the influencing factors are the following parameters: structural design, layer thickness and thermal conductivity of the used materials.

In the design process described here, only the boundary conditions of the topology within a finite element model were determined, with focus on the environmental aspects. The most important aspect of structural optimisation is the correct formulation of the target function. In this case, the thermal conductivity was set as the first target function, and all other parameters, such as the material input and the production effort, were set as the following ones in order to minimise the production costs. It was shown that the minimisation of the steel cross-section corresponds directly to the reduction of the thermal bridge.

The projected aim was to achieve a significant reduction in thermal conductivity compared to the existing, already improved brackets. While the thermal bridge is minimized, the load-bearing capacity has not been reduced, but could even be increased. This not only improves the environmental balance by saving resources, but also by reducing heat losses over many years to come.

This paper gives an overview of the calculation methods and test methods using the example of a façade fastening with the aim of structural optimisation with regard to previously defined target functions. Results are provided to show the bearing behaviour interacting to the heat transfer during the optimization process. The design rules are explained and the results are illustrated.

Keywords: Heat transfer, Advanced building envelope, Low energy buildings

Advanced Modelling of Concrete Structures for Improved Sustainability

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Abstract: The safe and long-term serviceability of concrete structures is one of the methods how to improve the sustainability of the concrete industry. This study presents a pilot application of an integrated system for online monitoring and service life prediction of concrete bridges. The system consists of strain gauges measuring the structural response coupled with a laser rangefinder for detection of the bridge-crossing

traffic. The measured data were used for the development of a computational model of the bridge. Next, the deterioration models were applied to the model to assess the long-term mechanical behaviour. In this study, we considered chloride-induced reinforcement corrosion. The numerical data are given for 100-years-long service life prediction.

Keywords: ageing management, bridge monitoring, finite element method (FEM), non-linear analysis, durability assessment

Analysis of the geometrical properties of fine recycled aggregates using digital image processing technique

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Abstract: The acquisition of natural sand and dumping of fine recycled aggregates (FRA) are two serious environmental problems that can be solved simultaneously by using FRA as replacement of natural sand in high-end applications. In the past, FRA has been considered an unwanted by-product of construction and demolition waste (CDW) processing, due to the high levels of contaminations and high content of fines. However, FRA is currently considered as a new secondary raw material with large potential. Due to the increasing interests in FRA it is of utmost importance to extensively examine their characteristics. To date, research has been done on the water absorption, density, chemical and mineralogical composition, and size distribution of the FRA. However, knowledge on the geometrical properties of FRA is limited. In this paper the geometrical properties of several types of FRA are examined using digital image processing (DIP). The effect of processing methods, crusher openings and crushing cycles are considered to gain new insights into the characteristics of FRA.

Keywords: Fine recycled aggregates, geometrical properties, digital image processing

Closing the Loop of Textile: Circular Building Renovation with Novel Recycled Insulations from Wasted Clothes

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Abstract: The implementation of new energy policies and standards for NZEB is expected to lead to a significant reduction of GHG emissions from building use in Europe in the next decades. On the other side, the growing pressure on insulation materials risks to significantly contribute to the exhaustion of the remaining carbon budget due to the high carbon intensity of conventional insulation for material processing. Consequently, storing carbon in construction products and promoting circular economies able to generate up-cycling processes from industrial or post-consumption waste are the key strategies to promote an effective transition toward a carbon-neutral society. Fashion & clothing is one of the manufacturing sectors which mostly contributes to waste generation and fossil GHG emission. This paper presents the main outcomes achieved from RECYdress project, which focuses on the valorisation of wasted textile collected by municipal districts to develop novel thermal insulations for building applications. Three alternative conceptual manufacturing processes were defined at lab scale based on different treatment of textile fibres, with produced specimens tested for thermal characterization. Finally, the LCA results of an ETICS application for façade renovation were compared considering as functional unit 1 m² of façade with similar thermal resistance.

Keywords: Textile wastes, circular economy, life cycle assessment, sustainability, thermal conductivity, transient plane source method

Mold growth on spruce and pine samples in steady state conditions: time of germination and maximum coverage

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Abstract: Wood is a material that is environmentally friendly and has minimal carbon impact. The durability of wood depends on ambient environmental conditions. This article deals with mold growth on wood samples under constant relative humidity (75 %; 87 %; 95 % RH) and temperature (23 °C). Pine and spruce samples with surfaces oriented along the three principal anatomical directions of wood were prepared. The occurrence of mold was studied by regular microscopic observations. The mold consortium was a mixture of *Penicillium sp.*, *Aspergillus sp.*, and *Alternaria sp.*

The first signs of mold growth on pine were observed after 7 days for 87 % RH and 12 days for 95 % RH, regardless the surface orientation. Molds on spruce began to grow in 12 to 26 days at 95 % RH in dependence on surface orientation: at first on tangential surface, then on transversal surface, and finally on radial surface. The lower relative humidity of 87 % resulted in a shorter germination time: 7 days for tangential and radial surfaces, and 21 days for transversal surface.

Keywords: wood, mold, germination, spruce, pine, *Penicillium* sp. *Aspergillus* sp. *Alternaria* sp

Experiencing circular design: stories of agri-food waste transformed into new materials for architecture

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Abstract: The application of the Circular Economy model, supported by the European Commission, can be the driver of an industrial and architectural conversion and, also, an opportunity to innovate production processes through the elimination of the concept of waste. Furthermore, the attention of public and private actors as well as policies and rules are now focused on accelerating the ongoing transition from linear to circular economy.

In line with this multi-sectoral shift, the paper intends to illustrate the results of the research activities carried out at the Politecnico di Torino in cooperation with Small and Medium Enterprises (SMEs) of the Piedmont region (Italy).

In particular, the article illustrates a double experience developed with two different paths: the *CIBUS*[®] research project (*Circular economy in the Building Sector from agri-food waste*) and the innovative master's degree course *Design and development the transition to the circular economy*.

Both experiences apply circular economy approaches to grape, hazelnut, and wheat waste to understand whether they could be new “ingredients” for architecture and design.

Keywords: Agri-food waste, Circular design, Sustainable building products

Natural Materials in Building Construction - Annual Evaluation

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Abstract: The construction industry's focus on a low-carbon economy will result in the need for a deeper examination of natural-based building materials. From an environmental point of view, the benefits of these materials are undeniable. However, it is necessary to consider their shortcomings in other areas of design in terms of building thermal engineering. This article observes and evaluates a wall designed for a wooden building with almost zero energy demand in year-round operation and subsequent assessment in confrontation with a different composition, seemingly more advantageous in thermal resistance and humidity regime. These assemblies are under long-term examination within the pavilion research of the authors' workplace, in laboratory conditions from the interior side. At the same time, they are exposed to the realistic boundary conditions of the external environment. The paper includes an environmental assessment of two compositions, variating in the used material. The research shows that the wall composition of natural materials is more advantageous from an ecological perspective and can also show favourable effects in terms of temperature and relative humidity regulation.

Keywords: timber-framed, natural building materials, temperature, relative humidity, environmental assessment

Hygric Performance of New Building Components for Vertical Green Gardens

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Abstract: The newly developed box-like panel lightweight element for vertical greenery was designed and built at University Centre for Energy Efficient Buildings of the Czech Technical University in 2020. A test site for testing green facade components is operated since spring 2021. Test samples differ in shape, arrangement of functional layers, water distribution means and irrigation patterns. The article presents and discusses measured data at selected test samples during growing season in year 2021. Physical quantities, such as surface temperature of plants, moisture content and matric potential of growing substrate, water inflow and outflow, and ambient boundary conditions, were recorded.

Keywords: vertical green gardens, real-scale experiment, hygric performance, watering patterns

The potential use of giant reed from Portugal as a thermal insulation material

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Abstract: The construction sector plays an important role in climate change. Thus, there is a pressing need to construct buildings that reduce heat losses, use natural and local materials, exploit renewable sources and ensure high comfort levels with a minimum environmental impact. Reed, considered carbon-neutral and a carbon dioxide sink material, has been used for centuries for diverse uses. Its properties and high availability made it a popular building material, as seen in Portuguese vernacular architecture. Knowing the properties of the reed is a crucial step to ensure successful heritage conservation, optimising these materials, and developing innovative solutions. This paper studies the potential of using giant reed from different Portuguese regions as a thermal insulation material. Giant reed board prototypes (15 x 15 x 5 cm, about 235 kg/m³) were built. Their thermal performance was tested in a hotbox, according to ASTM C136319. The results show that the giant reed harvested on the northern coast of Portugal has better thermal performance than reeds from other regions. However, regardless of the region of the country where the giant reed was harvested, it has a satisfactory thermal resistance ($Re \geq 0.30 \text{ (m}^2\cdot\text{C)}/\text{W}$), allowing its use as a thermal insulation material in the buildings.

Keywords: Giant reed; Thermal insulation material; Natural material; Low cost; Sustainability

Acoustical aspects of replacing traditional materials in building elements with renewable and recycled ones

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Abstract: Building elements, especially partitions, floors and external walls significantly affect indoor acoustic comfort. Their ability to reduce noise transmission from neighbouring rooms or from outdoors depends on the element composition and the building materials used. In Central Europe, the heavyweight masonry or concrete walls and slabs are typical elements both for family and residential buildings. However, increasing popularity of lightweight multi-layered structures is noticeable. This creates new opportunities for the gradual replacement of traditional materials with renewable and recycled ones, both for load-bearing components and for fillings and other layers of building elements. This paper introduces such design changes in relation to acoustics, particularly airborne sound insulation. The greatest attention is paid to the replacement of masonry and mineral wool insulation with timber and wood fibres. The overview is supplemented by examples of low-energy house external wall and timber wall with recycled infill whose sound insulation has been determined by measurements in the acoustic laboratory.

Keywords: building acoustics, sound insulation, sound reduction index, building elements

Prvok – Issue on 3D printing concrete building

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Abstract: Prvok is the first 3D printed concrete floating house in the (hidden reference). Additive manufacturing - 3D printing became a synonym of sustainable building of the 21st century. Its experimental manner and lack of world's standardization ISO approvals hold the 3D printing concrete method on the edge of usability and applicability and stop a broader spread of application in practice. Furthermore, the used material was newly developed MBS cement composite [1] prefabricated mixture with polypropylene plastic micro - fibres, which was not previously tested in large structures. What we achieved, was a practical realization of a 3D printed fully equipped and functioning concrete house as a habitable statue for a public event. In order to fulfil the request on insulation and avoiding heat bridges together with investing least material possible, we parametrically designed and implemented a wall system of construction. In order to be able to open the structure to the public, we tested it on the universal loading machines at (hidden reference) in scale 1:1. Testing fragments of the walls were also part of the research goals, which led us to the final design. In this paper, we present the results of the experiment together with the experimentally obtained data.

Keywords: 3D printing, Concrete, Prefabricated cement composite, Parametrically designed self load-bearing structure, Static loading tests.

Improving the properties of unburned earth to control the interior microclimate

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Abstract: The article concerns the problematics of unburned earth used as material for moulding formwork or clay plaster with lowered contraction, especially about interior unburned earth plaster with the heightened percentage of clay and therefore improved sorption abilities. By adding a plasticizer, it is possible to modify the fluidity of the mixture. With lessening the amount of water it is possible to lower the shrinkage. Furthermore, we can increase the ratio of clay to sand and thus we can control the indoor microclimate. This is because the clay provides adsorption properties. Unburnt clay has been widely used as a building material in the past around the world. In the last century, this material was rather despised. Nowadays, however, this trend is reversing and the unburnt clay is experiencing a renaissance. Increasingly people emphasize ecology, a healthy and balanced indoor climate, and demand buildings with low operational and energy intensity. All this can be offered by unburnt clay, because it is energy-efficient in production, easily accessible in almost all parts of the world, harmless, and beneficial to human health, as clay can contribute to the improvement of the internal microclimate to a much greater extent than other building materials, as confirmed by many scientific findings.

Keywords: earth, clay, microclimate

Innovative Technologies and Systems

Low Rents And Low Operating Costs In Social Housing - An Example From Germany

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Abstract: The social housing project “PassiveHouseSocialPlus” shows how low rents and low operating costs can be combined. Different concepts for reducing operating costs were implemented and tested in a refurbished and a new apartment building in Germany. In addition to passive house standard and efficient hot water preparation, the total of 42 low rent residential apartments are equipped with e.g. energy-efficient kitchen appliances, LED lighting and gray water usage for flushing toilets.

A special feature is the flat rate billing of most ancillary costs. Since the energy consumption for heating has been greatly reduced, space heating and domestic hot water are also included in the flat rate. Budgets for drinking water and household electricity have also been agreed in the operating costs. In order to inform the tenants how much of their budget is actually being used up, the consumption of water and electricity is shown to the tenants over time on a display in the apartment.

Basic results are that consumption of heat is about in the calculated range, but the budgets for drinking water and electricity are slightly exceeded on average. At the same time, the operating costs are around 30 % below the costs of comparable apartments.

Keywords: Social housing, operating costs, flat rate, budget, monitoring results, heating, water, electricity

Measurement and CFD analysis of a local radiant cooling solution

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Abstract: This paper entails an empirical and computational assessment of the air flow field in the close proximity of a vertically positioned radiant cooling panel. This radiant cooling solution differs from the conventional large-area radiant cooling systems (e.g., ceiling panels). It involves rather small-sized vertical panels positioned close to occupants. Moreover, the panels are designed so as to manage potential surface condensation of water vapor via integrated drainage elements. Hence, the panels can be operated with relatively low surface temperatures. The low panel surface temperature and its proximity to the occupants are intended to compensate for the potential lower cooling power due to the relatively small panel size. In this paper, we specifically explore the air flow field close to the local radiant cooling panel via laboratory measurements and CFD (Computational Fluid Dynamics). Thus, possible issues regarding discomfort due to draft and turbulence risk close to the radiant panel can be examined. To this end, a prototypical local radiant cooling panel was installed in a mock-up office room of a laboratory. During the experiments, the air flow speed was measured and simulated at several heights (between 10 and 110 cm from the floor) and distances (ranging from 1 to 50 cm from the radiant panel). The results allow for the evaluation of the draft discomfort risk as well as the reliability of CFD in reproduction of the measurement results. A further step involved the numeric analysis of the effect of the human model on the air flow pattern.

Keywords: radiant cooling panel, thermal comfort, air flow, CFD simulation

The Road to Circularity: a Framework for and Experiences in Collecting Road Data in a Circular Renovation Process

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Abstract: The construction and transport sectors both have a substantial impact on the environment. The construction, maintaining and renovating of roads involves both these sectors and the environmental impact of this work can be reduced. The basic principle of a circular economy is to close material loops and so retain the highest utility, quality and value of products, components and materials as possible. An important question in this respect is how to qualify and quantify material flows. Material and project passports seem to be part of the solution to improve insights and sharing information on quantities and qualities of materials used in construction projects. This paper has used a literature study on material passports and has taken into account current project management software used by a municipality, in order to share a framework for organising and collecting road construction data. Furthermore, various scanning equipment and procedures were employed onsite in an experiment in collecting actual road data. This resulted in a large amount of different data files that have been interpreted and incorporated into the existing database structure of the municipality. The insights gained may help other researchers, principals and contractors in the road construction industry in collecting and storing reliable data necessary to renovate roads circularly.

Keywords: road renovation, circularity, collecting data, material characteristics

Building-integrated photovoltaics (BIPV) combined with hydrogen-based electricity storage system at building-scale towards carbon neutrality

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Abstract: Electricity storage technologies in buildings are evolving, mainly to reduce their environmental impact and to improve self-sufficiency of buildings that produce their own energy through Building-Integrated Photovoltaics (BIPV) installations. To maximize self-consumption – minimizing the import of grid electricity – photovoltaic (PV) systems can be coupled with a hydrogen storage system converting the electricity to hydrogen by electrolysis during the summer season – when the on-site production is higher – and employing it during the winter season with fuel cells. This study focuses on the sizing constraints of solar hydrogen systems at building-scale using an innovative research-centre that will be built in Fribourg (Switzerland). It presents four stories and a mix-usage (office spaces and research facilities areas) and multi-oriented PV installation in order to produce enough electricity to achieve at least 50% of electricity self-sufficiency ratio. Using the PV production, this study aims to optimise the sizing of a hydrogen storage system allowing to reach the required self-sufficiency ratio with the lowest environmental impact possible. Ultimately, the global energy and financial efficiency of the system will be analysed.

Keywords: building-integrated photovoltaics, building energy analysis, solar hydrogen storage, fuel cell, battery storage system

INTERACT - Integration of Innovative Technologies of PEDs into a Holistic Architecture

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Abstract: INTERACT is an international research and innovation project which boosts the emergence of Energy Communities as one crucial building block to achieve Positive Energy Districts. It is designing an optimal organization and structure for Energy Communities based on success-factors of existing PED/PEN approaches, stakeholder needs and motivation, the available technologies, and a holistic LINK-based architecture. Technological and market-related solutions are delivered that maximize the benefit for the environment and society, considering the current legal framework and available business models. The project will develop a roadmap for the Energy Community's secure and reliable embedding into the power system structure, focusing on two pilot regions, a green-field project in Sweden and an existing municipality in Austria. The holistic architecture is used to ensure the integrity of the solution by harmonizing all interactions within the Energy Community itself, between it and the market, and the European power system. Its standardized and flexible structure allows the straightforward application of the roadmap to perfectly meet the diverse necessities of local communities, thus supporting the large-scale roll-out of the new control paradigms.

Keywords: Positive Energy Districts, Energy Communities, LINK Solution, Stakeholder Involvement, Distributed Energy Resources

Optimization Model of Solar Cooling System with Latent Heat Storage

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Abstract: According to information provided by the International Energy Agency (IEA) energy demand for cooling is the fastest growing end-use inbuilding sector. In recent years, interest in solar cooling systems has increased in the world and in Europe. Solar Cooling Systems are coming solutions to cover the rising demand of air-conditioning. Most of these systems are single stage absorption chillers using water as the working fluid and only a small part of them uses the options of latent heat storage. Based on previous research on solar cooling systems, the possibility of using phase change materials for latent heat storage must be considered.

The paper will present a study of a solar thermal driven air-conditioning system with the integrated a latent heat storage, with the aim of stabilizing the operation of heat storage, taking into account the volatility of solar energy, the impact of short-term operations and peak hours on the amount of heat produced. This means that the amount of electricity consumed to heat up the accumulation tank will be significantly reduced. The optimization model in simulation software will be performed to test solar cooling system with latent heat energy storage, with aim to investigate the efficiency of the developed latent energy storage and provide technical guidance for the implementation of such system in the practice. All indicators, including environmental impact and economic calculations, will be identified in order to identify the specific systems for foresight market uptake.

Keywords: Solar Cooling, Thermal Energy Storage, Phase Change Materials

Transformation and Acceleration of the Construction Supply Chain through Smart Factories

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Abstract: The European building stock is in high need of refurbishment due to its contribution to excessive global energy consumption. In the North-Sea Region (NSR) alone there are 22 million houses built between 1950 and 1985 with an annual CO₂ emission of 79 Mton. Current deep retrofits are carried out on a limited-scale production, which may result in climate targets not being met in time. To tackle the need for rapid renovations, prefabricated insulation elements with integrated intelligent technologies, manufactured in novel smart factories using mass customization, could offer a solution. This approach is also followed by the Interreg project INDU-ZERO. The project examines a far-reaching automated production and develops a blueprint for a smart construction factory in the NSR that can produce 15,000 renovation packages per year. This paper aims to quantify the acceleration potential of the supply chain by improving its production, logistics, and on-site mounting processes for Dutch single-family terraced houses. First, the design of the renovation packages and smart construction factories are introduced. Then, the procedure is elaborated on how the supply chain can be abbreviated. The results show that the renovation cycle time can be completed within two weeks through coordinated efforts between production, logistics, and mounting.

Keywords: Smart Factory, Renovation Cycle Time, Supply Chain.

Experimental Monitoring of Autonomous Curtain Walling Facade Module

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Abstract: This paper introduces an innovative concept for active wall-curtain façade modules aiming at high level of energy autonomy. The façade module consists of two opaque panels and one transparent panel integrating building integrated photovoltaics (BIPV) supported by embedded flat-plate batteries, in-façade thermoelectric air-conditioning (AC) unit, active shading, and LED lighting. The developed demo-prototype was deployed at testing facility and subjected to long-term experimental monitoring campaign to evaluate the energy performance in real-life conditions. The complex monitoring system captured key power and thermal fluxes, temperatures, mass flows and other operational states of the active wall-curtain façade modules. These measurements were assessed in form of monthly overview depicting total electricity consumption, on-site energy production, heating and cooling delivery as well as self-sufficiency and self-consumption indicators.

Keywords: active facades, energy autonomy, BIPV, in-façade energy systems, thermoelectric air-conditioning

Excellence in Building Science Education: Experiences with a Central European Experiment

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Abstract: The spectrum of educational programs in building science is wide and diverse. Whereas the academic landscapes across the world vary significantly, general discourse postulates certain rather broad characterizations. For instance, some schools, especially in the Anglo-Saxon context, are suggested to target a selective, private, and high-tuition approach. Others, particularly in the European context, have a more broad, public, and affordable nature. Even though highly simplistic and perhaps even misleading, this distinction has been frequently accompanied by the implicit assumption that true excellence (the so-called world-class) education in general and building science education in particular is possible only in the former settings. In this paper, we report on a specific academic degree program, namely the Master in Building Science and Technology (BST) program, which may be argued to cast doubt on this assumption. Initiated at TU Wien, Austria, BST was offered over a period of almost two decades. In this paper, we briefly present the genesis of this program, its features, its accomplishments, and its termination. Thereby, our primary objective is to inform similar and future initiatives, particularly across Central Europe, where many public universities exist, the building industry has a substantial presence, and the education of a future generation of technically competent, environmentally conscious, and socially responsible building planners and engineers is of essence.

Keywords: Building Science, Building Technology, Curriculum Development, Environmental Education, Multidisciplinary Teaching

A guideline to support the use of off-site solutions for façade retrofitting through BIM-enabled processes

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Abstract: The Architecture, Engineering and Construction sector requires an intense innovation process to reduce costs, intervention times, and improve energy performance. This is particularly true to increase the rate of deep renovations of the existing European building stock and therefore support the EU's 2050 decarbonisation targets.

In this scenario, prefabrication can be considered a game-changer for the construction industry: on the one hand, it enables the adoption of an industrial mindset to the design, manufacturing, and installation of façade components, with the related advantages in terms of time, cost and quality; on the other, it allows for the customisation of components thanks to digital, BIM-based design and fabrication tools. However, its adoption in retrofit operations is still limited due, among other factors, to a lack of practical experience and a limited number of actual demonstration cases. This paper introduces an operative guideline to support a more widespread use of prefabricated thermal insulation components for the energy retrofit of existing buildings in the framework of a BIM-enabled design and construction process. The guideline highlights the information flow and the role of each actor at every stage of the design and delivery process.

The proposed guideline is finally tested through its application to a case study to show the feasibility of the process and the advantages deriving from the adoption of an industrialised approach to façade retrofit in terms of faster installation times.

Keywords: Energy retrofit, MMC, DfMA, Off-site, BIM

Influence of heated facade air on the results of climate data measurement

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Abstract: Measuring climate data is a lengthy and technically challenging task. To record temperature data, small meteorological stations are located on the facade of the Research Centre building. Due to the position of the meteorological stations, which are mounted directly on the facade of the building, the temperature measurement sensor is not only affected by the solar radiation falling on the sensor housing, but also by the solar radiation falling on the facade of the building. The illuminated surface of the facade gradually heats up during the day and warms the air flowing near the facade. The temperature readings during the day may therefore be significantly distorted. To avoid this phenomenon, better-quality radiation shields have been purchased. The new radiation shield is characterized by a design that resembles eddy currents. The relationship between the shape of the outer and inner spiral is optimized, allowing vortices to form even in virtually windless conditions. In this paper, we would like to point out the differences in the measured air temperature data, according to the radiation shield used and the distance of the temperature sensor from the building facade.

Keywords: climate measurement, facade, radiation shield

BIM Based Hygrothermal Modelling of Building Constructions

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Abstract: The construction industry is currently one of the least digitised. However, due to recent technological developments, building information modelling and management (BIM) systems are increasingly being used to increase the efficiency of constructions and sustainable use of resources and increase the energy efficiency of buildings. In the case of new constructions or building renovations, properly designed hygrothermal behaviour of building materials, elements and structures are unavoidable to achieve the objectives mentioned above. Therefore, we can ensure the comfort of our users and healthy living space.

BIM is the most suitable and widespread method for digital management of building stock and related data and integration. With the possibilities offered by BIM, it is possible to integrate building physical modelling right into the architectural design process. However, with standard BIM systems, we cannot embed detailed material properties, weather, or the effects of the natural and built environment in the BIM model for heat and moisture transfer (HAM) modelling for hygrothermal performance evaluation at present. Furthermore, the data exchange process is one-way mainly and unregulated between BIM and numerical simulation tools.

In the presented paper, both a ClosedBIM and an OpenBIM based workflow are presented to bridge the gap between BIM and hygrothermal modelling of building components and constructions, that can contribute to the design of sustainable, economic and hygrothermal optimal building constructions and also could be a basis for artificial intelligence-based optimised design solutions.

Keywords: Building information modelling, heat and moisture transfer, numerical simulation

Moisture Drying Capacity of Mineral Wool Insulated Steel-Faced Sandwich Panels by Convection

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Abstract: This study analyses moisture dry-out from a steel-faced insulated sandwich panel by forced convection. Moisture convection performance was studied by laboratory tests and simulation. Two test walls with the lower parts close to the free water level were studied in a laboratory with and without convection. In addition, a real-scale wall was built to south orientate direction. Measurements were also used for simulation model calibration. The hygrothermal simulations were performed with the simulation tool Delphin in stable climatic conditions to determine the magnitude of the convection moisture dry-out capacity. Comparison of the measured and simulated relative humidity showed sufficiently good agreement. The results indicate that convection significantly improves dry-out capacity, especially during summer. However, during autumn and winter their dry-out capacity was smaller. To minimise the wetting of insulation, weather protection during construction and storage is necessary.

Keywords: drying of structures, sandwich panel, hygrothermal performance, moisture safety

Twin Rooms – New Experimental Test Cells for Testing Advanced Facade Elements

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Abstract: Nowadays the global trend is the integration of new materials, constructions and technological principles, which are simultaneously implemented in individual scientific and engineering disciplines. Reducing the energy intensity of buildings will increasingly resonate in individual political and professional circles. As a result, new fragments of building envelopes in the field of facade engineering are being developed and tested. Testing of building envelope is carried out either in static (laboratory) boundary conditions or in dynamic (climatic, real) conditions. The determination of the test method is conditioned by the specific intention or the investigated phenomenon within the construction of the building envelope. Currently, we finished the development and realization of the new experimental facility Twin Rooms for testing advanced elements of building envelopes in dynamic boundary conditions (in the real climate of Central Europe - Bratislava) in terms of building thermal engineering and energy efficiency of buildings. It is based on the concept of pavilion measurement. The essence of the research is that the outdoor climate is modelled by the conditions of the real outdoor climate. Test cells consists of a solar laboratory - two-room for a comparative study of the effect of solar radiation and heat transfer on energy consumption and indoor climate. The space of two identical laboratory rooms is situated inside a container - a pavilion, whose climate is a compensating space. Only the tested facade element walls are exposed to the outdoor climate. The exchange of energy with the environment is possible only through this measured facade wall. The article brings a detailed description of this experimental equipment, basic technical parameters of its technological circuits and methodology of experimental measurements.

Keywords: Experimental pavilion test cells, advanced facade elements, real outdoor climate

Operational energy and embodied impacts of retrofitting the window frames of mixed-mode office buildings

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Abstract: Design decisions normally consider the building's operational phase as the main criterion to reduce energy expenses in a building. In less efficient buildings, reducing the operational energy becomes the most important aspect to address in the design, construction and operational phases, for it represents the highest life cycle energy flow. However, energy-efficient solutions often reduce operational energy demand by increasing the building's embodied energy and greenhouse gas emissions, which have been overlooked in energy performance analyses. This work aims at investigating the operational energy and the consequent embodied impacts resulting from the retrofit of the window frame of mixed-mode office buildings located in a hot climate, with a focus on reducing the cooling energy demand. The method consists of an experimental study based on a case study, in which the EnergyPlus and the SimaPro software tools are used to evaluate the operational energy and the environmental impacts. Results showed that reducing the WWR and increasing the window opening factor conveyed operational energy savings but in some retrofit scenarios tested, these retrofit measures were counterproductive from the CED and GWP perspective. The main scientific contribution of this work is understanding the importance of the building analysis from a life-cycle approach. The results obtained can assist companies and designers to make their decisions from a broader environmental perspective.

Keywords: Energy efficiency, Operational energy, Embodied energy, Life-cycle analysis, Office building, Envelope, Retrofit

A review of the FIVA project: Novel Windows employing Vacuum Glazing Products

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Abstract: Vacuum glazing products have been in development for the past decades. Such glazing products regularly feature two parallel glass panes that have a small, evacuated gap in their interstitial space. To maintain the vacuum and the form of the glass product, regularly vacuum tight edge seals and a grid of distance pillars are integrated. During the years of development, the major focus was set on the production and durability aspects of the glass products, but relatively few efforts had been conducted towards the integration of such glass products into window constructions. Employing typically used double- and triple glazing windows' frames does not represent a feasible option. This is due to the specification given by vacuum glazing products, such as their small thickness and the requirement for sufficient glass edge coverage due to the major thermal bridge adjacent to the edge seal.

The authors, together with major players from the window producing industry, started a R&D effort that targeted disruptive new concepts for vacuum glass windows. Four different designs were developed that not only integrated vacuum glass products, but also featured unusual opening patterns, the latest generation of electrically driven fitting products, and specific seals. The thermal and acoustical performance of the prototypes was improved during the development via employment of numeric thermal simulation and lab testing. The present contribution illustrates the four prototypes and their performance, which – for instance- pertaining to the U_W -value is down to $0.6\text{--}0.7 \text{ W.m}^{-2}\text{.K}^{-1}$ at a glass thickness of less than 1 cm.

Keywords: Vacuum glazing, Windows, Thermal performance, functional prototypes, numeric thermal bridge simulation

Solar Shelter: Exploring Architectural Design Input for Industrially-Crafted Shading Devices

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Abstract: European Cities are strongly affected by the Urban Heat Island effect and Climate change impacts in recent and future summer periods. As such, the integration of passive cooling strategies is of increasing importance for the overall AEC (Architecture-Engineering-Construction) domain. Amongst other strategies, one of the most prominent strategies is the timely deployment of shading devices. While the shading device constructions connected to the inside, interstitial position or exterior of transparent building envelope components is thus an important part of the building, little change can be observed in the principal design and technology of such shading elements. Moreover, target conflicts between shading device deployment and architectural appearance can be observed in European Cities. For instance, the ensemble protection of the Vienna City morphology was – for a long time – considered to be more important than potent shading devices.

The present contribution presents the approach of an effort toward highly-esthetical, functional shading devices that provide – despite their architectural-design approach – a high degree of shading performance. Together with the window-building industry, four different shading device designs have been designed, developed and virtually tested. The design process was guided by critical reviews by domain experts and performance simulation efforts. We present the genesis of the four designs and their performance implications as a proof of concept that effective shading systems can be understood as part of the esthetics of a building and practical passive cooling device at the same time.

Keywords: Shading devices, summer overheating, passive cooling strategies, industry-university collaboration, urban heat islands, climate change, cooling demand reduction

Implementation strategies for renovation concepts based on participative planning

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Abstract: The potential for reducing GHG emissions by district renovation is largely untapped. It not only requires a thorough Energy Master Planning (EMP) of the district but also support of the decision-making processes. This can not only contribute significantly to reducing energy consumption and securing the location of energy infrastructure (generation, distribution, storage), but also to long-term sustainable development and climate neutrality.

Understanding the different solutions for district renovation which include combinations with energy supply and consumption is important in districts. The multi-owner structure in many districts requires another set of solution finding that is embedded in potential analysis, stakeholder analysis, participative planning, and multi-actor-Management. A district near Winterthur, Switzerland was analyzed in respect to the aforementioned aspects. Site visits and structured interviews with key stakeholders were used to collect data which was then used to analyze the technical-economic situation and to determine the possibilities for the future. The results show that the technical potential for a decarbonization is large. However, financial and social aspects are significant and lead to a delay in implementation. This demonstrates the complexity of district renovation and provides insights in success factors for decarbonization of districts. Based on the findings a number of recommendations are given. These include communication strategies and integration of community finance models.

Keywords: district renovation, renovation packages, building renovation, energy supply

ECOPOOL++: Developing a Sustainable Outdoor Heated Swimming Pool

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Abstract: The University of Algarve, in consortium with “Cristal Construções - Materiais e Obras de Construção Civil”, “Itecons - Instituto de Investigação e Desenvolvimento Tecnológico para a Construção, Energia, Ambiente e Sustentabilidade”, is developing a new concept of outdoor heated sustainable swimming pool, having a higher energy efficiency and lower environmental footprint. The main objective is to minimise energy and water consumptions, while assuring a comfortable temperature for the user, extending the utilization of the pool in the Algarve region, from the summer months, to at least 8 months of the year. In order to do it, different systems will be tested, including solar thermal and photovoltaic panels, inverted underfloor heating, heat accumulator exchanger with phase change materials and energy dissipating pipes. An innovative thermal insulation system will be included in the interior of the pool tank, together with a new system for the covering of the water plane. All these systems will be monitored and controlled by an industrial automation system that will communicate, via a programmable logic controller, using industry standard communication protocols, with a SMART platform, that will be in charge of the global operation’s optimisation. This platform will support an intelligent and predictive control and monitoring module, that controls the automation system to maximize the energy usage of the renewable sources, while assuring the user preferences. One of the main outputs of this project is the construction of a smaller scale prototype of a swimming pool, with the characteristics mentioned above, in order to test and validate the proposed developments.

Keywords: Outdoor heated swimming pool, solar energy, PCM heat accumulator, smart energy and water management system

Critical Analysis of Monitoring Indoor Air Quality In Education Centres

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Abstract: Indoor Air Quality perception in education centres has being a special concern based on their high occupancy and lack of ventilation. This study aims to present an overview of 20 relevant previous studies carried out in the last 5 years regarding monitoring and evaluating Indoor Air Quality in education centres. This analysis focuses on four specific aspects: general description of each study, ventilation typology, indicators measured and the number of locations measured. The results show that 60% of the studies were located in an urban context, 75% included primary schools and 75% included naturally ventilated buildings. Indoor and outdoor was measured in 60% of the studies. The most measured indicators were CO₂ (60%), PM_{2,5} (55%), Temperature (50%) and Relative Humidity (40%) all indoor. In 60% of studies were carried in more than five centres, mostly two rooms were measured and 35% of studies placed one sensor per room. This can be a major limitation, as the monitored data may differ significantly from the actual situation. In conclusion, the greater correlations found relating to what indicators have been measured, were the ventilation typology and the location of the building, which influences what parameters and concentration can be expected.

Keywords: Indoor Air Quality, monitoring, school, ventilation

Integral Planning – Potentials and Challenges for the Construction of Timber Buildings. A Teaching Example

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ABSTRACT: The term ‘integral planning’ describes the creative cooperation of experts from different disciplines with the aim of solving a complex, technical planning task. By involving all the disciplines and stakeholders at an early stage it is possible to achieve better solutions than in a linear planning process in which one designer directs the specifications to the respective specialist planners, who then add the corresponding engineering services. In the course ‘Integral Planning’, students from the fields ‘Architecture - Green Building’ and ‘Civil Engineering - Construction Management’ are working on a project in an interdisciplinary exchange over two semesters. Through the simultaneous interweaving of their specific skills, combined with a very free working method, the students are taught integral planning in a realistic setting with the aim to design a modular timber building system for temporary educational buildings according to the ‘cradle to cradle’ principle.

Keywords: integral planning, timber buildings, teaching example

Exploring the State of Knowledge and Gaps Regarding Sustainability within Viennese Construction Industry

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Abstract: Different approaches to assess sustainability goals are found in construction sector, mainly related to energy efficiency through building technology and high-tech components, to low-tech strategies based on passive planning methods, the use of renewable raw materials, and building certification programs, which, however, are mainly an evaluation of already built objects. Austrian construction industry is extremely fragmented and heterogeneous, making research, development and innovation an issue for companies. The core of this project is to bridge the specific gaps in knowledge within Viennese construction companies about sustainable architecture and respond to these urgent needs by developing a customized postgraduate course. Within the first phase of the project, team meetings, a workshop and an online survey were run to assess the state of knowledge of Viennese companies. By doing so, information deficits were identified, companies' need for knowledge was determined and topics to be transferred were raised.

Keywords: Sustainability, knowledge gap, expertise, industry needs, customized modular course

Characteristics of business models for innovation clusters in decarbonation projects

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Abstract: Roughly 97% of the European Union (EU)'s building stock is not considered energy efficient, and 75 to 85% of it will still be in use in 2050. Residential buildings account for around two thirds of final energy consumption in European buildings. The rate at which new buildings either replace the old stock, or expand the total stock, is about 1% per year. Similarly, the current renovation rate of existing buildings in the EU is about 1-2% of the building stock renovated each year.

The transformation of today's electric power sector to a more sustainable energy production based on renewable energies will change the structure of the industry. In this transformation towards a smart energy system interaction between sectors and technologies the main stakeholders (energy service providers; utilities) will face new challenges in their traditional way of doing business. Therefore, adapting their business models to remain competitive is seen as an important step.

We chose to characterize these business models by content, structure and governance of transactions for creating value by exploiting business opportunities. In the energy sector the following characteristics to the business models for energy supply have been identified.

The most predominant archetypes of business models for the energy supply are presented and discussed. Further, we propose to set up (or use existing) innovation clusters, based on these promising BM to ensure that innovative business environments (innovation clusters) will grow that have the potential for upscaling and replication of District Decarbonization Solutions. There are no specific business models for energy supply applied to renovation of districts. Uncertainties in the supportive measures for the application of DER makes it difficult to develop new business models for the utilities.

Keywords: business models, energy supply, innovation cluster

Bringing students closer to the issues of indoor environmental quality and technology using nEMoS device: an experience in Albania

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Abstract: The article presents the outcomes of a monitoring campaign and a survey performed in a school building in Tirana. Included in the Bilateral Agreement between the National Research Council of Italy and the Ministry of Education and Sport of the Republic of Albania, the research is based on environmental analysis, collection of data from monitoring of environmental variables and students' feedback. The monitoring of Indoor Environmental Quality (IEQ) was carried out with a wearable Environmental Monitoring System (nEMoS) for IEQ purposes, designed and developed by ITC-CNR based on the Do-It-Yourself (DIY) philosophy. The proliferation of the maker movement philosophy has promoted the diffusion of DIY-based technologies. The spread of this movement is observed outside schools but there is a growing interest among educators to introduce this philosophy in the students' education, approaching to STEAM (Science Technology Engineering Arts Mathematics) in a different and more stimulating way. The application of two nEMoS devices in two classrooms (in different locations) aroused the curiosity of students, bringing them closer to the world of technology with a practical example. It also increased their awareness about the overall IEQ conditions in the classrooms where they spend a considerable part of their lives.

Keywords: IEQ, Albania, school, sustainability, survey

Climate Change Adaptation

Development of a realistic scenario for the thermal energy demand of residential buildings in Bavaria till 2050

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Abstract: To achieve the climate protection goals, enormous efforts must be undertaken in all sectors: households, industry, commerce, and transport. Following a straightforward approach, the political objectives foresee, that in the building sector a massive reduction of energy use for the heat supply is accomplished. However, previous investigations have shown that this reduction of energy consumption is not feasible. Older buildings exhibit especially high energy demand and emissions. Yet, due to the low refurbishment rate, no substantial change of the heat demand can be expected within the next decades. By fully renovating the entire residential building stock, approximately 70 % of the final energy demand and related CO₂ emissions could be saved, still not enough to reach the political goals. Therefore, renovation or renewal of buildings and of the use of renewable energy sources have to be implemented jointly for achieving the desired savings.

The methods used to estimate the characteristics of Bavaria's residential building stock as well as its heating energy demand and related CO₂ emissions for the year 2050 are presented. Alternative goals are given which base upon the achievable final energy saving for a realistic renovation scenario accompanied by further reduction of CO₂ emissions by using renewable energies.

Keywords: Refurbishment, Building stock, Climate neutrality

Performance of two small experimental bioretention cells during first year of operation

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Abstract: The data on long term performance of low impact development for stormwater management such as bioretention cells are still sparse. The aim of this study was to evaluate experimental bioretention cells designed for long-term monitoring. Two identical experimental BCs were established in December 2017. The first BC1 collects water from the roof and the second BC2 is supplied from the tank for simulating artificial rainfall. The 30 cm thick biofilter soil mixture is composed of 50% sand, 30% compost, and 20% topsoil. Rainfall-runoff episodes, the effective saturated hydraulic conductivity evaluated for the first vegetation season in both BCs. Outflow water quality was measured from one bioretention cell during simulating rainfall. The first vegetation season has shown relatively high runoff coefficient of 0.72, while the peak outflow reduction for individual rainfall events ranged between 75% to 95% for the BC1. The runoff coefficient determined from artificial ponding events was 0.86 for the event started in the partially saturated biofilter, while it was nearly 1.0 for all subsequent artificial ponding events. The peak flow reduction ranged from 19% to 30%. Functionality of experimental setup has been successfully verified and monitoring of BCs continues. The elevated concentration of total suspended solids in the effluent was probably caused by relatively high fraction of clay in the sand filter. The next research results evaluated for the following vegetation seasons will lead to a better understanding of the long-term performance of BC.

Keywords: bioretention cell, biofilter, constructed soil, stormwater management

Adapting façade performances to climate change in Northern Europe: analysis of future scenarios for an office building in Stockholm

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Abstract: Future climate change will affect many human activities and sectors. Among those, the built environment will face several challenges about the varying climate conditions, including increased demand for summer cooling and related heat stress indoor conditions. In this framework, the paper presents the results of a recent study that investigated the global warming impacts on energy demand and indoor climate comfort for an office building in Stockholm over the next 50-60 years. The future climate conditions were investigated in 2070 and 2080 with different climate morphing approaches. Three different passive cooling solutions to decrease the cooling demand (such as external roller shade, electrochromic glazing, and internally ventilated shading) have been preliminarily assessed about thermal and optical properties, then integrated into the building energy simulation software IDA-ICE to evaluate the building energy performances regarding different Swedish climates, and finally economically estimated with a simplified LCC analysis. The results indicated that an increment of the cooling demand from 3 up to 24 kWh/m² and a reduction of the heating usage of 20-50% will be experienced in 50-60 years. The different weather data morphing approaches displayed the inherent uncertainties when future evaluations are performed, although similar weather patterns were found. The improvement of the solar and optical properties indicated a lower cooling and ventilation usage with reductions of about 10-16%. The electrochromic technology reported the lowest cooling demand (decrease up to 24%), while the internally ventilated shading option outperformed the others with an annual energy consumption 4-9% lower and the lowest LCC.

Keywords: Climate change, Building design, Passive Cooling Solutions, Solar Control Techniques

Climate-Resilient and Resource-Conserving Architecture through Renewable Building Materials and Microclimate Improvement

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Abstract: Due to climate change, together with the need to reduce the ecological footprint and the future resource shortages, a climate-resilient and resource-conserving architecture must be reinforced. Dealing with the issue of resources not only affects the materialisation of the building, but also the handling of resources on the building site. The interactions between the environment (sun, wind, precipitation), buildings, sealing, plants and people form a complex system in which small changes in few factors can influence the situation on a large scale. In this context, topics such as microclimate improvement around built infrastructure through greening and rainwater management, will gain in importance. The correct assessment of measures for a sustainable and resilient building is extremely complex and time-consuming and requires extensive, multi-layered know-how and experience. This paper analyses the project “House of Learning” (MAGK Architekten) and its immediate surroundings and focuses on its climate resilience and neutrality, proposing improvement measures based on the interaction of blue and green infrastructure and the building. The potential favourable conditions are evaluated through microclimate simulations and planning principles implying an integral approach which includes landscape gardeners, building planners and constructors, as well as decision-makers.

Keywords: climate resilience, sustainable buildings, renewable building materials, blue and green infrastructure, microclimate simulations

Implication of climate changes on design of structures

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Abstract: The climatic data on which the current generation of the Eurocodes are based are mostly about 20 years old, with some exceptions of recent updates at a national level. The second generation of the Eurocodes for structural design is expected to be nationally implemented within next few years and operational National Annexes should be subsequently developed and the climatic maps revised. Some models for extreme climate actions are still missing within Eurocodes including wind action effects due to non-synoptic storms, which are common in most of the world and are of increasing importance in Europe.

The aim of this contribution is to analyse how the impact of anticipated changes in European climate could affect the assessment of design weather parameters, including the partial factor design approach for structures according to Eurocodes, based on current knowledge concerning projection models of future climate in Europe.

Keywords: climatic actions, design weather parameters, climate change, probabilistic assessment, partial factors, target reliability

Sustainability and resilience in building design: discussion on two case studies.

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Abstract: Designing sustainable and, at the same moment, resilient buildings is a necessity to reach the UN Sustainable Development Goals by 2030. However, these two building design approaches – sustainability and resilience – are usually treated separately. Typically, resilience-improving strategies are placed only after a disruptive event and not at the design stage. It is clear that there is a substantial intersection between sustainability and resilience and this manuscript aims to determine more precisely the commonalities and contradictions seen in building design sustainable and resilient approaches as crucial elements for improving their cooperation in buildings. To accomplish this, the authors qualitatively analysed two case studies – respectively claiming to be sustainable and resilient – to understand if a sustainable building can also be considered resilient and vice versa. This paper is addressed to the private and public sectors that have a decisive role in building design and are determined to take tangible steps to influence decision-making and resilience-based solutions already at the design phase. In conclusion, once the commonalities of resilience and sustainability are highlighted, a building designed as sustainable or resilient will be in line with both long-term perspectives.

Keywords: building design; sustainable building; resilient building; synergies; contradictions; future threats

Innovation and experimentation of adaptive model for curtain wall

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Abstract: The entire construction sector is the protagonist, in recent years, of continuous research in terms of innovation of strategies and technical solutions leading to the progressive modification in the structure of the systems that make up the building envelopes, also to cope with climate change. Working on the envelopes today means, in fact, correctly adapting their performance reactions to dynamic climatic conditions. In this scenario, lies the current research, whose goal is the development of an adaptive model, using innovative materials based on the biomimetic approach, which can be applied to curtain wall systems. The investigation conducted through experimental evaluations in the laboratory, the TCLab testing section of the BFL of the Mediterranea University of Reggio Calabria, will provide the formulation of solutions to achieve an adaptive envelope that improves overall performance through new technological strategies. The methodological approach has been prepared on sequential phases, organized in thematic sections, related to a study phase and another application phase, which constituted a real added value to the research, realizing actions of applied experimentation with high-reliability results.

Keywords: climate change, building envelope, testing

Energy Efficiency and Energy Systems for Buildings

Use of Energy Profile Indicators to Determine the Expected Range of Heating Energy Consumption

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Abstract: A small set of query variables designed to collect information about the energy-related features of residential buildings is presented. These “energy profile indicators” include information about those visible characteristics of a building which have a notable impact on its energy performance and are simple to assess. The queries are an interesting source for a rough energy performance calculation for single buildings as well as for housing portfolios or housing stocks.

A method has been developed to transform the energy profile indicators into input data for a physical calculation model. It consists of procedures to estimate the envelope area, U-values, and efficiency values of the heat supply system. To all model input variables an uncertainty is assigned. If information from a query is not available, the model input is set to a state representing the average building stock and the uncertainty of this quantity is adjusted to a value reflecting the variance in the stock. The resulting uncertainty of the calculated energy use is determined.

Examples of the application of the method are given to show the influence of different unknown quantities including occupant behaviour. Experiences on the coherence with metered consumption are reported.

Keywords: Monitoring indicators, building stock, surveys, statistical evaluation, realistic physical model, uncertainties, target/actual comparison

Durability of Latent Heat Storage Systems

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Abstract: Latent heat storage represents technology with significantly higher energy storage density. The thermal energy storage capacity of building structures and storage units integrated into building services contribute to the energy flexibility of buildings. This paper presents results from laboratory experiments focused on the compatibility of heat storage media represented by phase change materials (PCMs) with materials of container. Material compatibility of selected PCMs with the plastics and metals were tested by a long-term experiment. Two organic-based and two inorganic-based phase change materials were selected for tests of compatibility with selected metals (aluminium, copper and brass) and plastics (PP-H, PE-HD, and PVC-U). Plastic-PCM compatibility was determined by gravimetric method. For evaluation of metal-PCM compatibility, calculation of corrosion rate was applied. The less mass changes and lower penetration of PCMs to the matrix was observed for inorganic-based PCMs compared to organic-based PCMs. In case of compatibility between metals and PCMs, the highest values of corrosion rate were calculated for copper immersed in inorganic-based PCMs Rubitherm SP25.

Keywords: Phase change Materials (PCMs), Compatibility of materials, Metal corrosion, Mass changes, Container, Latent Heat Storage Systems, Durability, Energy flexibility

Specifying Boundary Conditions for the Operation of Pipe Heating Systems with Impact on the Building Energy Balance

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Abstract: Unaddressed boundary conditions in the design of heating systems affect the energy balance of buildings, especially in buildings with very low energy consumption. Buildings with very low energy consumption are very sensitive to any heat flow and neglecting realistic heating water parameters affects their energy balance. Two simulation models of the end part of the heating system have been developed. The first simulation model shows the effect of the inaccuracy of the designed heating element on the calculated room temperature. The second model shows the hydraulic behaviour of the connection pipes of the designed heating element.

Keywords: radiator, heating system, energy balance, low energy building heating system

Increasing Thermal Protection with Use of Green Roof

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Abstract: The use of green roof is a great choice in case of climate change mitigation and reduction of urban heat islands. Positive aspects of green roofs during winter or the whole year round balance are often overlooked. The surface of highly insulated flat roof is overcooled during the night by the long wave sky radiation. This radiative cooling increases the thermal losses that are reduced by the existence of additional layers. The green roof composition layers also have their thermal resistance, which is not usually included within the calculation of thermal resistance using the EN ISO 6946. The presence of snow on the roof can also increase the resistance. This paper analyzes the measurement results of various experimental green roof fragments in Central Europe.

Keywords: green roof, temperature, experimental, measurement, winter, snow

Calibration of a summer building simulation model based on monitoring of user behaviour

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Abstract: Occupant behaviour is a field, that has always been of great interest to researchers. It could significantly modify the operation of the building and the user's energy needs, and it is also difficult to model it according to reality. Evaluation of measurements is a crucial step to calibrate dynamic simulations. Our goal was to analyse the indoor comfort conditions according to measurements, particularly in summertime, and find what solution closes the performance gap between the measured and simulated results. In this research, we investigated an apartment building that underwent an energy efficiency renovation. We have installed a weather station and monitoring sensors in selected apartments, with which we monitored the temperature, relative humidity, and CO₂ values of certain rooms, the presence of the inhabitants and the window opening and the operation of shading. In this paper, we focus on the monitoring and simulation results of the topmost apartment. The results can help us better understand how buildings work and how to implement user behaviour in dynamic simulations, how to calibrate the model according to measurements and make suggestions to increase the comfort of the residents.

Keywords: user behaviour, summer overheating, indoor comfort, in-situ measurement

**Evaluation of Thermal and Mechanical Properties of
Demonstration Wall utilizing Phase Change Cementitious
Materials**

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Abstract: International project PoroPCM involves partners from Germany, Czech Republic, Spain and Japan with the objective to develop new multifunctional Phase Change Materials modified porous cementitious nanocomposite (PoroPCM). Such material can be utilized for storing heat energy in the insulation layer of buildings compared to commonly used insulation materials since the phase change increases heat capacity. This enhanced feature reduces the amount of energy necessary for running the heating/cooling system. For the testing of the newly developed phase change cementitious composite a demonstration wall will be developed and tested for its thermal as well as mechanical performance. The topic of the paper is the description of the properties of the new phase change cementitious nanocomposite. The main emphasis of the paper is the description of the demonstration wall behaviour under typical environmental conditions. The wall design is supported by numerical simulation of the wall physical parameters. The numerical modelling involves the definition of suitable numerical models for the simulation of the thermal properties of the new phase change nanocomposite. The numerical model is then used to demonstrate the performance of the wall layer design. The presented pilot results show efficiency increase of the insulation material in the range 15–70%. Also modelling of wind resistance of the layered structure is included. The developed wall design and PoroPCM material will be tested and verified by a large scale test in the final year of the project.

Keywords: phase change material, cementitious nanocomposite, insulation performance, thermal analysis

Verification of window properties after 10 years of exploitation: results of measurements in the pavilion laboratory and the climate chamber

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Abstract: The article will deal with the analysis of measured data on a plastic window with thermal insulating triple glazing, which is suitable for low-energy or passive houses. The window was installed in 2011 in the test laboratory of the Department of Building Engineering and Urban planning, Faculty of Civil Engineering, University of Zilina (Slovakia), where it was tested under standard indoor climate conditions and real outdoor climate conditions. Surface temperatures on the frame friezes and glass system and heat flux density were recorded at a five-minute time step. In 2020, the window was removed from the laboratory and subsequently tested in a climate chamber. This paper will present the results of these measurements in terms of heat flow density waveforms, heat transfer coefficient, and total solar transmittance through the glazing. Subsequently, a simulation model of this window will be created in the environment of a computational program and its verification based on the measurements will be carried out. A series of calculations will be performed on the tuned model and analyses of the results and comparisons will be presented under the same climatic conditions as during the real measurements recorded by the meteorological station.

Keywords: window, triple glazing, climate chamber, pavilion measurement, building physics

Sustainable Development of Industrial Heritage

Research, protection, and possibilities of re-use of post-war industrial heritage in the Czech Republic. A discussion thus far missing on the protection of post-war building heritage

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Abstract: Industrial buildings from 1950s – 1980s, often architecturally, typologically and technologically very interesting, representing the development of technology industrial efforts of that era, are still only on the fringe of professional interest – not only in the Czech Republic but also worldwide. Industrial architecture built by the second half of the 20th century has already acquired its place in the professional debate on research and protection of industrial heritage and within the methodology of industrial heritage. Industrial archeology generally still deals only with a period of industrialization and it seems hard also for contemporary researchers to postpone the debate forward. Our contemporary research thus plays very important role in evaluation of a typical and atypical examples of industrial buildings of that time. While trying to formulate how this layer of industrial heritage can be protected and what problems can be encountered in efforts to reuse it, we are losing many iconic buildings and even an interesting cultural layer.

Keywords: industrial heritage, post-war architecture, re-use strategies

The New Industrial Revolution: Finding Life for the Buildings Left Behind

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Abstract: From large generating facilities to modest neighbourhood substations, public power structures are an exercise in dichotomy. Captivating yet mysterious, designed with both powerful function and beauty in mind. Quietly playing a role in the development of cities and supporting the activities of home worldwide, the magic of heritage power plants, pumping houses and substations is often hidden behind metal gates and pressed brick facades punctuated with oversized steel windows and carved decorative ornamentations.

Efforts to achieve global goals of carbon-neutrality paired with advancements in infrastructure, utility distribution and alternative energies now forces the reconsideration of many unique historic resources.

Brimming with astounding potential, power generation facilities present unique challenges that can be deterrents to redevelopment. Adaptive reuse celebrates the contributions of those who designed, constructed and operated the architectural and engineering marvels that powered the world while deterring exceptional building materials from languishing in landfills.

As an increasing number of sites are decommissioned how can they be positioned to power new experiences for generations to come? What redevelopment tools are available to incentivize the adaptive reuse of industrial heritage, specifically public utility architecture? How do government-led approaches to adaptive reuse differ?

Keywords: Power Plant, Adaptive Reuse, Rehabilitation, Heritage, Industrial, Decommissioning

Adaptive Reuse of Factory Chimneys – Industrial Heritage Symbols and Urban Landmarks

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Abstract: Industrial heritage buildings and sites are seen as an important part of urban regeneration and sustainable development strategies over the last two decades for a number of reasons. Of particular note is the genius loci that accompanies them, but also the potential to attract artists and creative industries. In this sense, factory chimneys are a strong visual element and also an important symbol. At the same time, thanks to their distinctive proportions, they have also become an unmissable part of the urban structure of cities, in which they can assume a compositional and orienting role (a landmark), comparable with church spires or belfries with all due respect. In order to design adaptive reuse of the chimney, it is therefore necessary to place it in a context that is not only spatial but also symbolic, both in relation to its immediate surroundings and in a wider context. Often, however, the subject of the new use of the chimney is only raised when at least the material context of the chimney was irreversibly altered; in extreme situations, the chimney is the only surviving element of the original structure. However, the lost authenticity - the originality of the preserved building structure or technological flow - also opens up new meanings and other possibilities for the use of a solitary chimney in a transformed environment. The contribution introduces adaptive reuse possibilities of the industrial chimneys within the sustainable urban development, considering both industrial heritage values and specific chimney construction limits.

Keywords: Factory chimneys, industrial heritage, adaptive reuse, sustainable urban regeneration

**A tool for Developing a Plan for the Renovation and Remediation
of Cultural Heritage Buildings**

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Abstract: Cultural heritage monuments are, to a large extent, public goods of collective consumption, and their preservation is in the public interest of the society as a whole. The benefits arising from the owner's investment and resulting from the existence and the use of a cultural heritage monument are usually not "consumed" solely by the owner, but, to a greater or lesser extent, by the whole society or a particular group. In the case of the renovation and remediation of cultural heritage buildings, the life-cycle costs are determined in the operational phase, before the intended renovation or remediation. They should be used to select an economically sustainable solution, with the maximum potential to preserve the cultural and historical value. The paper presents the application designed for the elaboration of plans for the renovation and remediation of cultural heritage monuments, developed in the form of a web interface. The application processes data at the level of individual structural elements. For faster and more comfortable users' work, a database of type objects is used, which combines primary data from the level of structural elements.

Keywords: cultural heritage, remediation, renovation

The Potential of Unused Railway Areas

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Abstract: Railway transportation faces many of the issues that are related to standard brownfields – due to changing technologies and industries, more effective systems (of traffic control in this case) and evolving needs many of the areas are actually no longer necessary for proper function of the railway. That is especially prominent in the case of railway stations, where a significant number of the stations use just a portion of their available tracks, buildings and areas (for example for unloading or repair). The remaining areas are sometimes sporadically used, but more effective and conscious management of the station could fairly easily lead up to the release of these areas for another, more useful function for both the city and the station. This paper will explore the differences between “standard” brownfields and unused railway areas like the typical ownership structure, particular location within the city and the effect station has on the city structure, composition and topography of the areas or the fact that railway areas are most often never really fully abandoned and they do continue to serve in some, albeit diminished capacity. Paper also aims to map out how much of the railways areas are underused or unused in Czech Republic (country with highest rail network density in the world). This paper will then recommend the best ways to use and revitalise them and it will show some successful examples of revitalization projects from all around the world.

Keywords: railway, unused, brownfield, revitalization

Implementation of Positive Energy District concepts and Energy Master Plans for Decarbonization of Districts

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Abstract: In order to be able to apply principles of a holistic approach to neighbourhoods and districts, often coined community energy planning in the literature, it is important to provide the necessary methods and instruments to master planners, decision makers, and stakeholders. There is a research gap with regard to the planning and implementation strategies and models used. Our research is based on literature and document analysis and qualitative interviews.

The results collect the characteristics of implementation models towards Positive Energy Districts (PEDs) and analyse which energy supply options exist and which market actors are needed for PEDs. The consequences for a larger rollout of the concept are discussed. From the analysis of the results, the conclusions are that integrated energy planning is more important than ever. Understanding the different dimensions of sustainable development in combination with energy supply and consumption is important to plan and realize settlements that not only contribute significantly to reducing energy consumption and securing the location of energy infrastructure (generation, distribution, storage), but also in terms of long-term sustainable development and in specific climate neutrality.

Keywords: positive energy districts (PED), Energy Master Planning (EMP), implementation plans

Urban Development and Retrofitting

Lifelong Learning of Property Managers in Enabling Sustainable and Energy Efficient Residential Buildings: Experiences of CARE Project in Tampere Region

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Abstract: The existing building stock causes 40% of the total energy consumption in the European Union. The high energy consumption together with ageing buildings put strong pressure on renovation of buildings and lowering of CO₂ emissions. The Directives on Energy Performance of Buildings (EPBD) and Energy Efficiency (EED) were established to urge and steer the activities in the EU member countries.

There are about 90,000 housing companies in Finland. They consist of 1,7 million apartments and 2,7 million residents, which makes housing companies a significant energy consumer. Around 50% of the building stock in Finland was built between 1960s and 1980s. The average level of technical building systems is decent. Measures are still needed to tackle the increasing maintenance backlog and energy consumption objectives.

Management of housing companies consists of the general meeting of apartment owners and a board elected by the general meeting. In addition, a vast majority of housing companies have a professional property manager whose role corresponds to CEO. The property manager's expertise plays an essential role in planning and execution of maintenance and energy efficiency.

The role of the property manager calls for multidisciplinary competencies and continuous learning. The CARE - Resource efficient caretaking of residential buildings project implemented flexible courses and training for property managers to enhance their technical understanding of energy efficient renovations and retrofit of new energy solutions.

Keywords: low-carbon buildings, property management, retrofitting, housing company, lifelong learning

A Methodological Approach for Life Cycle Assessment of Refurbishment Measures – From Building to Neighbourhood and Municipal Level

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Abstract: Life cycle assessment (LCA) in the building sector has become a widely used method for quantifying environmental impacts of a building over its entire life cycle. Currently, however, no standardized procedure exists for considering refurbishment measures. In addition, the LCA, according to the European standard EN 15978, is limited to building level only. This paper shows how a methodological LCA framework of refurbishment methods can be applied at three levels: single building, neighbourhood, and municipality. Initially, the proposed methodological approaches are introduced while the framework rules are defined for each of the three levels. The system boundaries of the LCA differ regarding the assessment levels within the given methodology and are adapted accordingly. In addition, the three levels of assessment are defined by the accuracy of measurement results, and data requirements, as well as by the specific value of the calculations and the ownership of the building stock. The assessment levels provide a specific quality and quantity of environmental indicator results. Thus, the complex interrelationships of the assessment levels are shown. The developed framework for the environmental assessment of refurbishment measures provides comparability at the building level. At the neighbourhood level, emissions from refurbishment measures are compared with the reductions of emissions through heating energy demand. Ultimately, the potential of refurbishment measures at the municipal level can be identified on a large scale and used as a decision-making tool.

Keywords: Life cycle assessment, LCA framework, refurbishment, neighbourhood level, municipal level

From Intelligent Building to Smart City – A Case Study

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Abstract: This paper is to provide some insights to professionals on the evolution of smart city, to present its concept and appropriate elements based on the author's 40+ years of experience in international building development projects.

With the oil crisis in the 1970s, the use of alternative energy sources such as solar energy and energy saving measures were explored to combat the threat of fossil fuel supply. The concept of intelligent building to improve the productivity of the occupants and energy saving was then emerged in 1980s, followed by the focusing of the built environment like green building and sustainable construction in the 1990s. Various metrics were developed by different countries for assessing green building provisions e.g. LEED in a more structure manner. Building resilience has recently become popular for abating the increasing natural disasters. The features of intelligent building, green resilient building and smart city will be illustrated by making references to developments which were designed and project managed by the author.

On a more macro scale, with the rapid advancement of ICT in recent years, the concept of smart city has been advocated. The various definitions of smart city would first be depicted. Based on these definitions, the attributes of smart building and the respective features were suggested. The appraisal of the designed provisions of a mixed development project in Southeast Asia was then illustrated with suggestions on further elements to enhance its smart city characteristics.

Keywords: Intelligent Building, Green Building, Building Resilience, Smart City

Land Use Change Impact on Urban Land Surface Temperatures: A GIS-supported Satellite-based Case Study

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Abstract: This paper illustrates the use of GIS techniques and satellite data in order to analyze the impact of land use change on the local urban microclimate. Specifically, a case study is presented that concerns the city of Vienna. Thereby, satellite-based images were used to classify the city of Vienna into four zones toward the computation of land surface temperatures in two reference years. The classified maps were then statistically projected into the future, resulting in predicted land surface temperatures. The findings highlight the relationship between urbanization and temperature rise in the urban context. The study used data from Landsat 8 satellite in 2013 and 2020. Land cover maps were generated with QGIS for past and current conditions and future land cover maps were projected and corresponding land surface temperatures were predicted. The analysis of satellite data highlighted land surface temperature increase in the city of Vienna. This rise in land surface temperatures correlates with urbanization-driven change in land use and land cover.

Keywords: Urbanization, land surface temperature, GIS, satellite data

Dynamics of Apartment Building Renovation Investment Costs Based on Estonian Reovation Grant Scheme

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Abstract: While energy prices have increased substantially recently, we also observe that renovation prices have increased twofold within last decade. This could seriously affect the motivation to invest in building renovations because of negative yield and in turn jeopardise the carbon reduction plans. Therefore, we attempt to show some evidence of renovation cost dynamics based on sample of 112 apartment buildings which received state support for deep energy renovations during 2010 and 2017. We found that investments started out very cautiously in 2010. Eventually renovations were embraced as rational investment and renovations ambitions grow with prices. Construction price index grew during the study period 20 percent and renovations over two times. We could not confirm the popular hypothesis that demand pressure will also increase prices. However, most significant increase of renovation price was due to the additional construction works and quality improvement. This was especially evident after the redesign of grant rules in 2015 which allowed more indirect construction works to be eligible for the subsidy.

Keywords: energy renovation, construction cost, procurement, apartment buildings

Reintegration Of Karachi Port Through Sustainable Adaptive Reuse Of Abandoned And Underused Industrial Buildings.

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Abstract: The economical capital and one of the most important cities of Pakistan gain its popularity due to the reputable Karachi port. In ancient times, the city of Karachi was known by different names in different reigns like *Korokala* and *Debal* and was conquered by some of the famous conquerors like Alexander the great and Muhammad bin Qasim due to the importance of its seaport. However, the modern seaport and most of the tangible and material heritage related to the port were constructed by the Britishers in the 19th and 20th centuries. It was because of the seaport that the Britishers conquered the city and started developing Karachi port, and due to the port, the area of Karachi grew from a small fishermen's village to a bustling metropolitan city. During the second industrial revolution in the late 19th century, the Britishers developed Indian industries in such a way that they were dependent on British capital goods. To transport the goods railway and maritime routes were constructed in the mid and late nineteenth century, The port of Karachi was one of them.

Karachi port still is the center of main logistic transportation of Pakistan, but some of the buildings of heritage value are neglected on this site. After the 9/11 tragedy in the US, due to security reasons, Karachi port was restricted to the public. Now, the security situation is better, and the port can be reintegrated and made accessible for the public through sustainable adaptive reuse of the abandoned or underused buildings. Karachi is a congested city with few places for recreation, reintegrating this site can open opportunities for tourism at the same time showcasing the industrial heritage of the city.

This paper wants to articulate the potential of industrial heritage. But the latter in Pakistan is not yet recognized as part of a heritage discourse. The port offers a rich case study due to its layered history and its variety in typologies.

Keywords: Industrial heritage, reintegration, adaptive reuse, seaport

Is it all about the windows? Residents' values in residential heritage buildings

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Abstract: Reducing energy and associated carbon emissions from the built environment is fundamental to meeting our climate goals. Retrofit of existing buildings is therefore a key strategy. Heritage buildings present particular challenges for retrofitting because of their traditional construction and need to retain historic values. Replacing windows is often a critical element of a low energy retrofit, but for heritage buildings this can be problematic

This paper explores the values that residents invest in their windows, and the opportunities and challenges for retrofitting heritage fenestration. Qualitative data from 16 case studies of heritage buildings in the county of Cumbria, UK, is examined to gain a greater understanding of residents' views, which are often neglected in policy approaches. Findings show that residents, in both designated and undesignated heritage buildings, value their original windows and appreciate the thermal benefits of traditional features such as shutters or curtains. Residents generally considered complete window replacement unacceptable but were more positive about options such as secondary glazing or internal shutters. Challenges, including costs and finding skilled tradespeople to produce shutters or undertake restoration were identified. The paper concludes with the implications of these findings for retrofitting heritage fenestration for carbon reduction.

Keywords: Heritage buildings; Windows; User values; Retrofit

**Advancing Circular Economy in the Existing Building Stock:
a methodology to support building characterisation for
sustainable refurbishment design**

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Abstract: The lack of standard practices and platforms for assessing refurbishment strategies towards Circular Economy (CE) and their impact in global warming constitutes a challenge for the decarbonization of existing building stock. Incorporating data and feedback from designers and practitioners since early design stages is important to feed a multi-criteria dynamic process with multiple dimensions, which must be assessed under a life cycle perspective. To tackle this issue, this paper introduces a new methodology to support the implementation of tailored refurbishment strategies for increased recovery, reuse and recycling of construction materials. The final objective is to build a methodological framework for sustainable refurbishment design in a BIM environment, which aims to facilitate standardized practices in the construction sector, regarding CE, with a positive impact in the mitigation of global warming and the decarbonization of the building stock. To test the development of this methodology, a case study building in Lisbon, corresponding to a 1919-1945 archetype is analysed, making use of its BIM model, where BIM standardization criteria and circularity indicators are discussed, in order to be implemented as a Plugin for Circularity.

Keywords: BIM-based platform; building archetype; building automated characterisation; CE; methodological framework; sustainable refurbishment design

Oldest Concrete Vaulted and Arch Bridges in the Czech Republic – Evaluation and Preservation of Their Historical Value

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Abstract: The paper is related to a research project focused on tools for an evaluation and preservation of the historical value and function of arch and vaulted road bridges. It deals with the beginning of use of concrete vaulted and arch bridges in the area of the Czech Republic from the first structures built at the end of the 19th century up to the time just before the WWII. The paper includes examples of built structures as well as a general summary and development of the used technical solutions. Important part of the paper is a proposal of criterions for evaluation of their structural and historical value.

Keywords: Concrete Bridge, Arch Bridge, Vaulted Bridge, Existing Structure, Repair of Bridges, Strengthening of Bridges, Historical Value of Bridges, Structural Value of Bridges

Densification Of Single And Two-Family Houses Considering Green Space And Mobility

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Abstract: The question of future energy-efficient creation of living space is becoming more and more important in many cities due to limited space availability and simultaneously increasing settlement pressure. Against the background of the desired space, resource and energy efficiency, cities are steadily-focusing on internal development and densification. In order to encourage a sustainable urban development, the existing densification potentials need to be mobilized by addressing the owners directly, to convince them for the measures to mobilize the given potentials. Therefore innovative GIS methods and databases are used within the research projects “BONSEI!” and “BONUS” in order to detect these potentials. Following is a gradually constructive consultation that helps house owners, depending on their needs and wishes, to find potential construction actions to increase the living space within their parcel. The research project “BONUS” further tackles problems and concerns, which come with densification, by maintaining high quality green spaces and at the same increase the usage of sustainable forms of mobility and try to reduce car usage within the districts.

Keywords: densification, internal development, sustainable development, green space

Prioritizing sustainability-oriented upgrade actions for social housing in Brazil

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Abstract: The current need for buildings to meet new environmental, social, and economic sustainability requirements creates an urgent demand for viable solutions. Internationally, social housing (SH) development is mostly triggered by policies and regulations, which stimulate interventions, create financing mechanisms, and designate agents conducive to retrofit processes. European directives for energy efficiency and the recent call for a 'retrofit wave' have an evident influence. In Brazil, SH follows a different delivery and management model, based on the public offer of housing units and the immediate ownership transfer once they are completed. Post-delivery interventions depend exclusively on the effort and expenses of the occupant. SH budgets leave little or no margin for extra spending. The issues that arise to implement upgrade in this context are related to the following questions: What are the priority actions in upgrade processes? What type of financing would be required/is available? What is the project execution model and who are the stakeholders involved? This article focuses on the first issue (prioritization of actions). A systematic literature review examined the reported sustainability-related housing improvements. Next, a critical review of a Brazilian building label and two international sustainability assessment methods supported ranking upgrade actions according to the relevance assigned in their respective contexts. Finally, a panel of construction professionals provided insights regarding the technical feasibility and intrusiveness of its implementation in both single- and multi-family SH projects. Our findings show that minor upgrades, such as changing hydraulic or electrical fixtures or landscaping, usually do not cost more than implementing them from the outcome and are equally applicable to single- and multi-family SH projects. But, when highlevel (deep upgrade) interventions are on the table, costs rapidly increase due to the need to substantially change existing systems or supporting structures, which makes them often financially and/or technically unfeasible.

Keywords: social housing; sustainability; upgrade, prioritization

Rescue of a stone bridge with respect to current condition and standards

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Abstract: A three span stone masonry bridge dating back to the middle of the 19th century, still in the roadway network, is assessed to prevent its demolition. Its industrial heritage value and ecological concerns were the principal reasons for the assessment. The carbon footprint of the stone arch replacement would be approximately 200t CO₂ emission owing to 430 m³ reinforced concrete in the new structure. The owner demands that the bridge remains a full service part of the second class road network without limitations. Its load capacity is checked against available standards. A combination of a structural analysis commercial software for linear 3D analysis with a dedicated noncommercial 2D code for the dominant nonlinear phenomenon – tension cracking of the bed joints is employed. Elastic interaction is accounted for of the three principal components of an arch bridge, the cracking stone vault, the backfill of cohesionless soil and the reconstructed pavement slab of reinforced concrete. The bridge with the new pavement meets the national and European standards conditions. The owner decided to preserve the bridge. Besides a cultural monument, considerable energy, CO₂ emissions and natural resources can be saved in accordance with the of the sustainable development goals.

Keywords: natural resources preservation, sandstone, bridge, arch, stress, displacement

How municipalities should approach the transformation of public spaces

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Abstract: Public spaces are the living rooms of cities, accessible to everyone without any restrictions. Public spaces are the calling card of the city; they are where the community comes together. Their design either enables or complicates community life. From a visitor's point of view, public spaces are the first things to be noticed and encountered in a city. Due to various circumstances, public spaces sometimes fail to meet the abovementioned features or do not fulfil them to the degree they should. Thus, the presented methodology guidelines may help small cities representatives who do not have the professional or personnel capacity to deal with public spaces through planning, preparation and contracting the public spaces studies, which leads to a quality assessment of public spaces. The guidelines also include tips for improving public spaces, recommended practices for public participation in planning the transformation of public areas, and a site assessment form for a non-expert's perspective.

Keywords: public space; public participation; applied research; interdisciplinary co-operation; guidelines

Circular Construction

Circular Design in the Global South

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Abstract: One Planet Sustainable Buildings and Construction Programme (SBC), led by the Ministry of the Environment, Finland and co-led by RMIT University and UN Environment Programme was initiated in 2015. In its fourth and last two-year work plan 2021-2022, the focus areas are circular built environment and responsibly sourced materials. SBC has published State of Play for Circular Built Environment reports from Africa, Asia, Europe, Latin America, Middle East, North America and Oceania in a Special Track in the Beyond 2020 Conference together with a Global report that drew recommendations for action. In addition, the relevance of circularity in UN 2030 Agenda Sustainable Development Goals (SDGs) and indicators is being continued to be mapped in a global survey to understand circular underpinnings for buildings and construction. The present focus is on Africa, Asia and Latin America, where case studies are collected following a common framework. The objective is to provide reliable performance data for responsibly sourced building materials exploiting circularity while supporting some related SDGs across the social, environmental and economic considerations. This paper presents key findings from this study, largely derived through case studies in the Global South. The results show that not all stages of the building life cycle are addressed through local examples.

Keywords: case studies, circular built environment, sustainable buildings and construction, life cycle, sustainable development goals (SDGs)

Catalogue of Construction Products Containing Secondary Raw Materials from Different Industries and Municipal Waste

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Abstract: The building industry consumes a large amount of primary raw materials and also contributes significantly to the production of waste. Applying circular principles in this field to reduce resource consumption and waste production has been investigated in several projects considering the reuse or recycling of construction and demolition waste. However, consumption of primary raw materials can also be reduced by re-targetting waste from different industries and municipal waste to produce new construction products. Thus, opportunities for the recycling of industrial and municipal waste were investigated in this project. The main output is the catalogue, which provides an overview of products with recycled content and secondary materials with the potential to be used in the construction industry such as blast furnace slag, ash, and energy by-products. Also, it contains a list of valid requirements for the use of recycled materials under specific conditions of the Czech Republic. In addition, examples of good practice are presented to break the existing behavioral barriers to the use of secondary raw materials in the Czech construction industry. This contribution summarizes the findings in the field of industrial and municipal waste recycling and its further use as secondary raw materials in the construction industry.

Keywords: Waste, circular economy, secondary raw materials, primary raw materials, recycled materials, recycled content

Measuring circularity from buildings to neighbourhoods

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Abstract: The circular economy (CE) aims to eliminate the concept of pollution and waste generation, maintain the integrity of the product over several use cycles, and focus on closing material and energy loops. Circular metrics are relevant for monitoring, reporting and communicating CE implementation progress. Applied to buildings, these metrics deliver structured assessments through standardized indicators, which establish a common language among the agents involved, help implement strategies to assess the circular potential of technical options. Studies dealing with circularity metrics for buildings are still scarce and somewhat variable within an overall common framework. Applications to neighbourhoods are even more incipient. This study applied selected metrics to two building cases with different constructive characteristics, to improve the understanding on how information on circularity is conveyed. The selected metrics highlighted the circularity challenges for the two building designs. However, such metrics disregard the environmental impacts required to induce circular flows and loop closure. It is herein proposed that such metrics are paired with environmental performance profiles produced by e.g., life cycle assessments (LCA). The concept of 'nested indicators' could be applied to neighbourhood and city scales by referring to the LCA concept of functional equivalency as the 'relevance' weighting criterion.

Keywords: circular building; indicator; metric; circularity; circular economy

Ecotoxicological assessment of recycled aggregate and concrete via aquatic biotests

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Abstract: With the growing consumption of primary raw materials, the need for recycling of construction and demolition waste (CDW) arises. According to international and national regulations, any waste must be tested for ecotoxicity using a leaching test followed by chemical analysis and a set of aquatic toxicity biotests. Standardized leaching procedures have also been developed for construction materials and products and are used in common practice. On the other hand, studies aimed at direct determination of ecotoxicity are still lacking. Acute toxicity tests with unicellular algae, freshwater crustaceans, and marine bacteria are among the most popular for determining the ecotoxicological potential of recycled aggregates or concrete samples. The article deals with the perspective of semichronic and chronic tests with extended exposure, as well as testing of leachates obtained from leaching events for more than 24 hours. Results of performed experiments were compared and evaluated. From the point of view of sustainability, it is necessary to develop an optimal experimental design for the ecotoxicological evaluation of recycled aggregate and concrete. The conclusion of the paper is the evaluation of possible methods and their combinations.

Keywords: recycled aggregate, recycled concrete, construction and demolition waste (CDW), leachate, ecotoxicity

Circular design strategies through Additive manufacturing: MoDom, a "circular building" housing model

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Abstract: The doubling of the global use of raw materials in the last century is an established environmental emergency due to an all too common 'take - make - dispose' linear development model. Strategic plans within the Green Deal, such as the Circular Economy Action Plan, highlight the key role of building design as an enabling driver for process cyclicity. Against this backdrop, the paper describes the results of an experimental research project aimed at the technological design of a 'circular' housing model. The integration of circular economy principles into the design process was pursued through the technology transfer of Additive Manufacturing principles as an enabling technology of Industry 4.0. The research is based on the first phase of critical analysis of two types of case studies: one referring to Circular Buildings, the other referring to 3D printed buildings, through a common reading method based on "circular" indicators extrapolated from the current literature. The evaluation of the results obtained determined the prerequisites for designing a replicable Circular Building model by 3D printing using a lignin-based biopolymer. The adoption and combination of these seemingly opposing themes was a key strength and asset to the project in terms of benefits such as energy savings, lead time, and cost savings at all life cycle stages.

Keywords: additive manufacturing, circular building, bio-composite

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