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//
**HEALTHY HOUSES
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CONFERENCE PROCEEDINGS**

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FASÁDY NA BÁZE PŘÍRODNÝCH MATERIÁLŮV - VÝZVY A PERSPEKTÍVY// BIO-BASED BUILDING ENVELOPS — CHALLENGES AND PERSPECTIVES

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ABSTRAKT

V súčasnosti pozorovaná tendencia vytvárať udržateľné stavby a zvyšovanie environmentálneho povedomia vedie ku znovuaktivovaniu bio-architektúry ako alternatíve ku ostatným konštrukčným princípom. Veľmi často si toto zameranie na udržateľné konštrukčné princípy vyžaduje použiť lokálne materiály a produkty. Z tohoto pohľadu majú ekologicky prijateľné materiály pochádzajúce z rastlín a zvierat veľkú pozornosť architektov. Vďaka ich všestrannému charakteru je možné z materiálov na prírodnej báze (z angl. bio-based materials) tvoriť budovy prispôbené akémukoľvek lokálnemu kontextu. Tieto materiály majú kapacitu byť vhodné pre akýkoľvek kontext, aj keď majú rôzne formy vzorov. Budovy, ktoré sú vytvorené z prírodných materiálov sú teda vnímané ako poctivé a úprimné. Táto prezentácia preto popisuje kľúčové výzvy týkajúce sa možných inovácií v prírodnom staviteľstve z pohľadu vývoja v materiálovom inžinierstve a tvorivých konceptoch, ako aj nástroje a služby pre zlepšenie prevádzky a údržby fasád.

ABSTRACT

The recently observed tendency for development of sustainable structures and increasing environmental consciousness leads to reactivation of bio-architecture as an alternative to other construction materials. Very often, focus on sustainable construction principles requires the use of local materials and products. In this perspective, environmentally friendly materials originating from plants or animals are of great interest to architects. Due to their versatile character, bio-based materials enable creation of buildings adapted to any local context. Bio-based materials give an impression of being suitable for any context, even if they have different forms or patterns. Therefore, buildings that are made of natural materials are perceived as honest and sincere. This presentation will describe the key challenges regarding possible innovations in the bio-based building sector from the perspective of development in materials science and design concepts as well as tools and services for improved facade management.

INTRODUCTION

The main purpose of a building envelope is to provide basic shelter in order to protect occupants. Nowadays, building façades perform many more functions than in the past, offering security, privacy, and comfort as well as benefits such as aesthetic pleasure and improved well-being [1]. Increasing environmental consciousness and development in materials design leads to reactivation of bio-architecture as an alternative to other construction mate-

rials. Consequently, the rising trends in implementation of wood and derived products in the building sector is often noticed. Emerging tendencies and innovations in the building sector can be divided to four groups: focusing on improvement of façade functions and services as well as concentrating on environmental and human-centered aspects (Figure 1). Current and novel functionalities Biomaterials enable prefabrication and fast installation of building façade. Due to a favourable weight to load-bearing ratio, they

allow erection of multi-story structures while providing great design freedom. The main role of building façade is to separate two environments: external and internal. Standard static façades require constant human attention to regulate the microclimate of buildings. The term “adaptive façade” (called also “responsive” and “dynamic”), includes systems capable to react to external conditions by means of controlling humidity, daylighting, solar shading, insulation, radiant heat exchange, ventilation, and energy harvesting [2]. The materials often implemented in adaptive façades are rather non-renewable (e.g., glass, steel, phase changing materials), but implementation of bio-based materials as active façade elements was recently demonstrated and is under investigation [3].

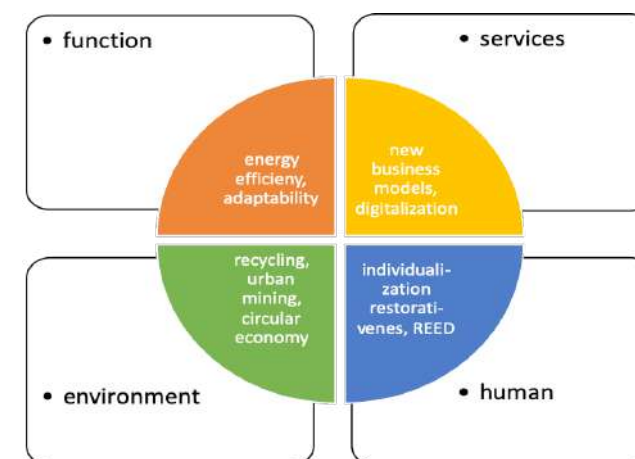


Figure 1. Recent trends present in building façade architecture

The design of building façades, in addition to waterproofing, insulation, and aesthetic functions, requires energy efficiency in order to follow policies for reducing energy consumption [4]. Buildings are already responsible for 40% of energy consumption, 36% of CO₂ emissions, and a lot of effort is directed toward improving building energy performance [5]. Many bio-based materials (e.g., fiberboard, flax fibers, hemp fibers, jute fibers, and sheep wool) possess low thermal conductivity ($0.05 \text{ W m}^{-1} \text{ K}^{-1}$) and high moisture diffusivity ($1.1 \times 10^{-6} - 1.2 \times 10^{-5} \text{ m}^2 \text{ s}^{-1}$), which can classify them as good candidates for use in interior thermal insulation systems without water vapor barrier [6]. Their hydrothermal and energy performance, comparable to non-renewable materials, make them interesting alternatives due to their natural origin (Figure 2). Renewable materials are often mentioned as important alternatives for the building sector. In fact, the definition of nearly Zero-En-

ergy Buildings (nZEB) as a building with very high energy performance, where the nearly zero (or very low) amount of energy required should be covered to a significant extent by renewable sources produced on-site or nearby, was introduced in 2010 [7]. It is foreseen that, until the end of December 2020, all new buildings in the EU will fulfil the requirements to be classified as nZEB. However, even if the overall advantage of nZEB related to lower environmental impact is attractive, very often the high initial investment cost makes this concept less economically affordable. This, however, might be a trigger for new development in materials science and in design of new solutions being, at the same time, efficient from a performance and economic perspective and also sustainable.



Figure 2. Natural materials used for building insulation – Cu-erden Valley Park Visitor Centre

CURRENT AND NOVEL SERVICES

The novelty in the services offered to buildings is related to new business models and digitalization implemented during planning, construction, and use phases. Implementation of the new materials as well as new functionalities requires additional attention and maintenance actions. Cost of maintenance and retrofitting of buildings is often high compared to the total building costs. In extreme cases, façade with integrated building services can make up over 90% of a project's initial investment [8]. Application of new materials and façade systems, which are not yet fully validated in service conditions, brings new challenges for investors and contractors. New business models, called “façade leasing” and used as a performance-delivering tool for building façades, has been recently tested in Delft. It is suitable to be implemented for both new construction and to retrofit existing

buildings. In this concept, clients require energy performance and comfort service delivery instead of the façade itself. Maintenance actions and eventual replacements belong to contractor/investor duties. Such an approach might accelerate market uptake of new technologies and optimize reuse and recycling of façade elements. This might significantly speed up development of novel solutions and, at the same time, gain client acceptance and confidence. Moreover, it might be a solution that mitigates not optimal decisions being taken during a project's planning phase, where a focus on initial investment costs frequently prevents the adoption of more robust or energetically efficient systems [8]. Consequently, the total cost of ownership (TCO) can be lowered.

Another tendency observed recently is related to continuous development of digital fabrication, computational design, simulations, and building information modelling (BIM). BIM is a design procedure that includes the administration and management of the digital representation of physical objects uniting the planned building (structure, installations, and systems). The general idea is similar to the "internet of things" concept, where every physical object has its virtual representation. The difference is that BIM is used to design and plan buildings. BIM files enable storing and exchanging information and networking on the design and building process. BIM systems are utilized by individual designers, organizations, and government offices. In the context of material aging, BIM is a very powerful tool that makes it possible to examine potential changes in material properties and appearance and plan future maintenance, which is relevant in the context of building façades. Adding extra dimension to BIM allows better understanding and controlling of the construction process (delivery of materials, construction costs, and maintenance schedule). Figure 3 presents new functionality recently implemented in BIM architecture. 4D BIM adds an extra dimension of information regarding construction sequencing and timing. It allows observation of how the project will be developed and how much time will be needed to accomplish sequential steps in the construction. 5D BIM provides information regarding economic aspects, including cost of purchasing, installation, maintenance, and replacement. 6D BIM provide input regarding energy consumption and sustainability. The energy use can be estimated during the

design process but also monitored during building occupation. 7D BIM simulates building management from design to demolition by providing project lifecycle information. It delivers additional information besides the costs of construction by including data regarding installation date, warranty, required maintenance, and expected performance in time. 8D BIM is related to safety issues. It includes manuals, emergency plans, etc. Recent challenges are related to filling new BIM dimensions with reliable data representing a big portfolio of services and constituents (including bio-based building materials).



Figure 3. New BIM dimensions

ENVIRONMENTAL ASPECTS

The construction sector represents one of the biggest sources of waste in terms of volume with approximately 70,5 million tons of wood waste generated annually [9]. Construction and demolition leftovers are widely acknowledged as one of the most important sources of waste [10]. They are usually divided into new construction, renovation, and demolition. However, only one third of waste wood is currently recycled. According to the urban mining concept, city building wastes could be considered as a huge stock consisting of many resources [11]. In this case, different reuse, recycle, and end-of-life options are available. A building example that follows principles of the circular economy is Circular Pavilion designed by Nicola Delon and Julien Choppin. The façade of Circular Pavilion was made of 180 wooden doors recovered from the rehabilitation of an apartment building. The motivation for designing it followed the idea of one person's waste is another person's resource.



Figure 4. Circular pavilion in Paris made of recycled doors

Environmental aspects are particularly relevant when analysing tendencies in today's building market. Currently, about 35% of the EU's buildings are over 50 years old and around 80% of the current building stock will still be present in 2050, indicating a present and developing demand for renovation [12]. In 2015, renovation accounted for 57% of the total construction market, with residential buildings constituting 65%. The renovation potential of buildings in the EU is huge – up to 110 million buildings could be in need of renovation [13]. Bio-based building materials, therefore, fit very well with the general concept of minimizing the amount of waste based on the "reduce-reuse-recycle" paradigm. As mentioned before, favourable weight to load-bearing ratio makes them perfect candidates for up warding existing buildings, especially in the urban contest where the erection of multi-story structures is restricted by space limit. Sustainability in this perspective is achieved by using engineered wood products, smarter materials, optimizing design and layout, reducing long-term maintenance costs, and recovery of materials at the end of their service life. Sustainable construction principles require the use of local materials and products. In this perspective, environmentally friendly materials originating from plants or animals are of great interest to architects. An example might be the Living Building Challenge certification program and sustainable design framework, which requires a certain percentage of building materials to be originated from within a certain distance to the construction site [14]. Cuerden Valley Park Visitor Centre, presented in Figure 2, is one of the first European examples targeting this concept.

HUMAN-CENTERED ASPECTS

Besides protection against the outdoor environment, façades allow transfer of information regarding building function, prestige, and status. Different building materials allow architects to create unique perceptions of the building and its integration (or not) with its surroundings. They manifest the architect's vision and reflect the personality of the owners. This is particularly relevant in urban contests when especially tall buildings are commonly used for shaping a city's image. The big variety of timber-derived façade materials allows tuning a building's outlook in order to fulfil client expectations. Bio-based materials give an impression of being suitable for any context, even if they have different forms or patterns [15]. Therefore, buildings that are made of natural materials are perceived as honest, sincere, and well-integrated with their surroundings (Figure 5).



Figure 5. Brockholes Visitor Centre in UK

Sustainable design aims to create buildings that respond to the environment and react to climate change. The future, and the next stage of green architecture, is restorative architecture (Figure 6). In this concept, a building gives more to the environment during its lifetime than it takes away during its construction. Such buildings tend to integrate and improve the surrounding environment while being environmentally friendly. They are designed to have net-positive impact on the environment by providing energy, capturing and reusing water, allowing farming, creating ecosystems for plants and animals, and increasing local biodiversity.



Figure 6. Principles of restorative architecture

Any natural material perfectly fits to this concept. By intentionally including natural materials in architectural design, occupants are automatically reconnecting to nature. Consequently, implementation of wood as a material in biophilic design creates affinity to the natural environment, which is particularly relevant in an urban context that might disrupt this connection (Figure 7). Biophilic design encourages this affinity by creating natural environments for living, working, and learning [16]. Using wood as an exposed material in buildings, where humans can interact with it, is known to create positive psychophysiological effects for building users. Incorporating nature into the built environment, either directly (e.g., potted plants) or indirectly (e.g., tree-like columns), can reduce physiological and psychological indicators of stress while increasing productivity, creativity, and self-reported levels of well-being [17]. Research in this area provides evidence of positive health impacts for wood use in the built environment [18].



Figure 7. Living façade on the shopping centre wall in Brescia

The emerging area in this study field, called Restorative Environmental and Ergonomic Design (REED), describes building design paradigms that can provide guidance for the use of natural materials in buildings in order to improve human health [19]. REED is integrating frameworks for improving occupant and user health, increasing safety, and improving building management. By using natural materials, REED aims to design and create ergonomic, accessible, adaptable, and sustainable buildings. Integrating nature into the built environment, by enabling views of nature, using natural materials (preferably local), and reflecting local ecology in building design and use, is assumed to improve building users' perception of the natural environment and, therefore, motivate them to care for it [20]. This represents a shift in building design from minimizing environmental harm towards creating positive impacts for the natural environment, building users, and the whole of society [1]. Consequently, it moves restorative architecture toward the regenerative stage and allows its further evolution.

Summary

The façade is an important element of the building, creating a first impression and expressing information about building function and status. Wood and other bio-based materials are becoming increasingly more acknowledged in modern architecture due to their aesthetic value, improved performance, and sustainability. This manuscript described the key challenges regarding possible innovations in the bio-based building sector from the perspective of development in materials science and design as well as tools and services for improved façade management. Rediscovering of wood as a building material, even if challenging, certainly provides comfort and well-being for future users as well as increased sustainability of architecture. Bio-based building materials can, therefore, move the traditional building concept towards restorative and regenerative architecture.

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