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ActaReBuild MSCA-DN PROJECT - ACOUSTIC AND THERMAL RETROFIT OF OFFICE BUILDING STOCK IN EU

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ABSTRACT

MSCA Doctoral Network projects are essential in fostering international collaboration and developing interdisciplinary, innovative solutions. The Horizon MSCA-DN project "ActaReBuild" advances sustainable retrofitting solutions for office buildings in Europe.
The unique feature of this project is that it addresses both the acoustic and thermal performance of buildings in their conversion to other uses.
The project consists of ten Individual Research Projects performed by ten Doctoral Candidates (DCs) under joint PhD supervision.
Research within "ActaReBuild" includes developing innovative materials such as customisable mycelium bio-composites, recycled plastic composites, bio-based materials optimised for acoustic and thermal performance and metamaterials. It addresses novel solutions to improve low-frequency airborne sound insulation in lightweight constructions and refines descriptors for airborne sound insulation of facades, addressing spectral and temporal noise features. In the framework of the project, advanced measurement techniques for remote in-situ measurements for building facades are developed. It explores the balance between airtightness, energy efficiency, and acoustic performance and application on biotic materials for lightweight building envelopes, which significantly reduce embodied carbon and support circular economy principles.

Keywords: *building retrofit, acoustics, thermal physics, MSCA-DN*

1. INTRODUCTION

ActaReBuild project is MSCA – DN (Doctoral Network). The scheme aims to train 10 highly skilled doctoral candidates, fostering their creativity, enhancing their innovative abilities, and boosting their employability for the future [1]. Candidates are enrolled in joint PhD programmes and are supervised by joint supervisory committees. The ActaReBuild project started on 1st September 2022 and is a 4-year project funded under the Horizon Europe scheme.

2. BACKGROUND

Recent European research initiatives have focused on mitigating climate change by implementing energy-efficient building retrofits to achieve near-zero energy use and reduce urban heat islands [2-3]. Although these projects have achieved notable advancements in material and energy efficiency, acoustic performance is often overlooked. Long utilised in construction, recent advancements in bio-composites have enhanced traditional biomaterials like wood, straw, and mud [4-7]. A promising method utilizes mycelium-based composites made from agricultural waste, offering the potential for excellent acoustic absorption while replacing non-renewable materials [8]. A well-known example of sustainable material reuse involves incorporating

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rubber or plastic to create various products that dampen vibrations in floating floor systems [9], and there is also a possibility of using such material in the concrete industry [10-12]. However, the acoustic and thermal performance of materials like granulated plastic and glass [13] requires more research.
In addition to material innovation, phase change materials (PCMs) aid in passive thermal regulation by stabilising indoor temperatures and lowering energy usage [14]. Acoustic metamaterials, designed for targeted sound insulation, show potential for lightweight partition systems; however, they are still largely overlooked in extensive building retrofits [15]. Another developing technology is ethylene tetrafluoroethylene (ETFE) cushion systems, commonly utilised in lightweight façade and roofing applications for their transparency and energy efficiency [16]. Despite this, the acoustic properties of large ETFE structures are still not adequately characterised since conventional room-based tests [17] are inappropriate for them. Advanced in-situ measurement techniques, such as surface impedance measurement with intensity probes or laser Doppler vibrometry (LDV), provide potential solutions [18-19].
Acoustic assessment methodologies also require refinement. Existing sound insulation descriptors, such as Single Number Quantities (SNQs) defined in ISO 717 [20], are often not sufficient for evaluating modern lightweight and hybrid materials, particularly at low frequencies [21]. Furthermore, Life Cycle Analysis (LCA) is increasingly recognized as essential for assessing the sustainability of construction materials, with studies indicating that substituting traditional materials with bio-based alternatives, such as timber, can halve the embodied carbon footprint [22]. However, guidelines for incorporating these materials into large-scale retrofit projects remain underdeveloped.

3. FOCUS OF THE PROJECT AND RECENT FINDINGS

So far, the following results have been obtained. Research, where myco-materials were developed using Pleurotus Ostreatus mycelium grown in various natural substrates, was performed. The materials have undergone testing for compression and tensile strength as well as thermal conductivity. The study highlights the potential of agricultural residues for sustainable construction, with sugarcane bagasse composites exceeding other samples in strength and insulation. While drying and autoclaving are still CO2-intensive, solar drying could reduce the environmental impact. Despite challenges in scaling, mycelium's ability to bind waste materials makes this method economically attractive [23]. Another study has been performed which examined the degree of accuracy on the tortuosity of a porous material using ultrasound transmission measurements. Compared to pulse measurements, the method shows improvement in signal quality. Subsequently, various configurations of tilt angle and transducer spacing were examined, and the results obtained were comparable to other studies dealing with the characterization of tortuosity [24].
Experiments on the performance of a novel bio-based material in terms of sound transmission, sound absorption coefficients as well as thermal properties were conducted. The results showed improvement in monitored parameters in comparison with conventional materials. Several ideas of possible use were concluded [25-27].
The experiments on the acoustic performance of recycled material in the form of loose plastic granules – ethylene-vinyl acetate, polyethene, and polystyrene – were performed. The measurements showed the possible alternative to conventional materials while addressing the waste disposal challenge [28]. Furthermore, the waste material was used to fill cavity resonators. Because of their sound absorption performance, they could be used as an alternative to fibrous materials, although only in exterior applications such as noise barriers [29].
Another part of the project's research focuses on applying PCMs in building construction. The results of the investigations involve composite components that are created by impregnating a highly porous material with two different paraffinic PCMs. The findings emphasize calcium silicate panels as a possible host material for PCMs [30].
A comparative study of various methods for calculating the transmission loss of double panels with the application of metamaterial, demonstrating the broader applicability of the transfer-matrix method in predicting transmission loss, was conducted [31]. The following research was aimed at the possibility of improving the sound transmission loss of a metamaterial unit comprising a membrane with a centre mass used for sound insulation of heat pumps in residential buildings [32].
The use of the LDV method for estimating sound power, as well as the exploitation of the Nyquist-Shannon sampling theorem for pressure estimation criterion in flat plates, are shown in the next study [33].
The assessment of the life cycle of materials is another topic of interest in the framework of the project. The research published in [34] emphasizes the possibility of converting fibrous agricultural resources into insulation products that require less energy. It also investigates innovative methods such as electrospinning and additive manufacturing for bio-

based applications composites. The further study provides a foundational basis for developing methodologies to influence local policies that promote sustainable strategies [35].

The study related to the relevance of various listening test methodologies for evaluating the influence of façade sound insulation on the perception of outdoor noises was also presented [36]. Another study recommends better incorporating all aspects of noise annoyance in future listening test experiments based on the overview of the methodology and sound stimuli used in previous studies [37].

Two experiments on the relation between sound insulation performance and airtightness of constructive solutions were also conducted [38-39].

Another important topic addressed in the project is the life cycle of constructions based on ETFE foils/cushions. The published study on this topic assesses the environmental impact of ETFE foil's End-of-Life scenarios using LCA, emphasizing recycling as the preferred option while considering incineration if transportation emissions are too high [40]. A different study Analyzes uniaxial hysteresis tests on ETFE foil, revealing 33 years of wind load history, supporting material reduction, and validating the method while recommending bi-axial tests for accuracy [41].

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