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Development of advanced multifunctional façade systems: Thermo-acoustic modelling and performance

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Abstract. The development of lightweight and multifunctional curtain wall systems, which integrate different technological solutions, is aimed at achieving increasingly higher requirements related to energy efficiency as well as indoor environmental quality in non-residential buildings. On one hand lightweight and thin façade elements present several advantages (such as construction time, space, and transportation savings, less weight on primary structure etc.), while facing the challenge of guaranteeing the required thermal and acoustic performance and achieving legislative compliance on the other. In the framework of the Horizon 2020 Project Powerskin+ a new concept of multifunctional façade, which combines high performance insulation, energy harvesting, heating system, and latent heat storage capabilities is under development. Within the design process of the different sub-modules (opaque and transparent), performance calculations are carried out by means of existing simulation tools, or ad-hoc developed models for more complex systems. In this study, the authors present the main steps required to accelerate the simulation-based design process and the future thermal and acoustic optimization of the novel lightweight and multifunctional façade element.

1. Introduction

In the framework of the EU H2020 POWERSKIN PLUS project [1,2] (here in after named PS+), the development of an advanced façade system, which can integrate different technological solutions, aims to achieve increasingly higher requirements related to energy efficiency and indoor environmental quality in non-residential buildings.

An extensive simulation campaign had to be carried out, assisting in developing a new concept of opaque and transparent façade modules that combine high-performance insulation, energy harvesting, heating system, and heat storage capabilities (both electric and thermal). Within the different sub-modules' design process, performance calculations were carried out by means of both commercially available simulation tools and ad-hoc developed models.

The development of complex façade systems embedding several technologies, i.e. Building Integrating Photovoltaics (BIPV), Latent Heat Thermal Energy Storage (LHTES), Vacuum Insulation Panels (VIPs), Microfluidic-glass, 2nd life electric Li-ion battery storage, and embedded heating systems, requires a complex multiscale simulation approach which involves thermal, energy, and acoustic aspects.

In this paper the approach used to define strategies and methodologies to accelerate the initial investigation phases of the façade module development in the future project steps to obtain optimised opaque and transparent façade modules is presented.

To achieve this goal, the three main steps foreseen in the project are presented:
- STEP 1: Collection of material properties
- STEP 2: Framework on commercially available tools
- STEP 3: Preliminary simulations, methodologies and tools development

2. Collection of material properties

In a complex multiscale simulation process, involving several research and industrial partners, sharing a common information dataset about materials type and properties represent an essential coordination step to facilitate the comparability and the reliability of the results obtained at the different simulation scale.
A database was created in a shared platform always accessible to the project partners helping to quickly select the properties of each material that will be potentially implemented in the façade modules. Moreover, the physical properties assessed on the materials specifically developed in the framework of the project will be implemented and made available to all the project partners. Besides the properties needed to assess the thermal and acoustic performance of the PS+ façade modules, the material database was created to additionally collect the information useful to make structural, LCA, and LCC analysis.

3. Framework on commercially available tools

The information regarding the thermal, optical and acoustic performance of the module are needed to detect the optimised panels configuration. To determine these performances, preliminary simulations are needed. Since the module configuration are constituted by different materials and components each characterised by own features, the identification of the most suitable simulation tool could represent a complex task. To simplify this process, a summary table which collects all the commercially available simulation software for thermal/energy and acoustic performance simulation was created.
The tables were completed with several information; a first main classification was carried out based on the "simulation scale". For the different simulation scale, the collected software were clustered according to the following information: Simulation scale (component or whole building), Time-domain (steady-state or dynamic), spatial domain (1D, 2D, 3D), Calculation method, Envelope type (opaque or transparent), acoustic simulation, co-simulation capabilities.
Then the simulation scope of each software was identified and classified into different main groups according to each tool's capability.
Finally, a set of specific simulation capabilities were reported to have a more detailed classification and identification of each tool's potential. Table 1 summarise the software categorisation.

Table 1. Summary of the software categorisation

Simulation scale	**Simulation scope**	**Required simulation capabilities**	
		Thermal/energy	**Acoustic**
Component scale	Heat stress, Thermal bridging, Heat balance, Mass transport, Optical properties, component acoustic	Phase Change Materials*, Moisture transport, accurate modelling of natural ventilation in cavities, Radiation/convection in closed cavities, Air source in open cavities, PV production*, Heat source in layer*, Moisture source, Fluid circulation*	weighted sound reduction index R_w, transmission loss, weighted sound absorption coefficient (aw), mid-frequency value of the sound scattering coefficient, single value of diffusion coefficient of surfaces
Whole building scale	Heating/cooling demand, Heating/cooling load, Indoor thermal comfort index, Natural lighting, Indoor Air quality, Façade acoustic	Phase Change Materials*, Moisture balance, HVAC, PV production*, Implementation of control algorithms	weighted apparent sound reduction index R'_w, weighted standardized sound level difference of a façade $D_{2m,nT,w}$

* Required simulation capabilities for technologies that will be specifically adopted in the PS+ project

4. Preliminary simulations, methodologies and tools development

In this step, a matrix intended to be adopted as a guide for quick detection of the tools or method to be used accordingly to specific simulation purposes was developed. Moreover, an overview which identifies the planned simulation activities and the related specific developed methodologies was created. Finally, preliminary simulation aimed at testing the software capabilities was presented.
The main structure of the matrix was subdivided into three main categories corresponding to the simulation scale (material/element, component, whole building). In each category, the simulation purposes, the target values, the Key Performance Indicators (KPI) and the tools to be used were listed. For every single component analysed, a set of information was reported. In table 2 a description of the column content is outlined.

Table 2. Matrix structure

Simulation scale	The scale of the analysis reported above (Material/element, component, whole building)
Material/technology	In the “material/element” scale, this section was filled with several materials to be adopted for the opaque and transparent module assessment.
PS+ target values	The PS+ project required the achievement of several performance targets; in this column, the description of the target typology is reported (e.g. U-value)
Additional target values	In this column, an additional numerical target value is reported; this target is linked to the goals reported before, and the achievement of this value is intended to optimize the module/element performance.
Evaluated KPI	The column reports the performance parameters to be analysed
Risk	Critical aspects that might compromise the component service life or its efficiency i.e. Thermal stress.
Values	The values associated to each envisioned risk are here indicated i.e. maximum VIP temperature
How to	This column contains a brief description of the methods and the tools to be used for the analysis reported before
Software/tool	The name of the software or the “ad hoc” tools to be adopted is reported.

5. Conclusion

The preliminary steps to approach the simulation activities needed for the development of the PS+ advanced façade modules are presented.
The Material Database has facilitated and harmonized the input data selection to be used in the ongoing simulation activities. The material database is intended to be continuously implemented by the partners for the whole project duration. The framework on commercial tools was used to help the partners select the most suitable software to perform the thermal, and acoustic simulation at the different scale and stage of development of the project.
The preliminary simulation, methodologies and tool development have provided useful support for the start-up of the façade module development by identifying the main relevant Key Performance Indicators, the correspondent target values and how to simulate their accomplishment in the next project phases.

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References

[1] https://www.powerskinplus.eu/ <accessed 12.03.2021>
[2] Favoino, Fabio; Fantucci, Stefano; Resalati, Shahaboddin; Fan, Mizi; Corker, Jorge. H2020 Powerskin+: Carbon-neutral non-residential buildings. OPEN ACCESS GOVERNMENT 29(2021), pp. 406-407.