PLEA 2018 HONG KONG
Smart and Healthy within the 2-degree Limit

Investigations on the Application of Nanomaterials to Improve the Environmental Performance of Buildings

ALI AL-GRAITI, DR. ROSA URBANO GUTIERREZ

School of Architecture, University of Liverpool, Liverpool, UK

ABSTRACT: Nanotechnology is commonly regarded as a crucial step ahead in technology advancement to tackle some of the environmental problems of our contemporary building construction industry. The main characteristic that distinguishes nanomaterials is size, being defined as materials whose parts are smaller than 100 nanometres. This change in size of the material's structure, enables the generation of new material interactions with energy, opening new possibilities for performance improvement, which in turn leads to a reduction of energy consumption and greenhouse gasses emissions. Nanotechnology appears to be one of the alternatives to pursue the desired impact minimisation, while meeting the required comfort standards to provide good living conditions to the building's occupants. But, how reliable is this statement?

KEYWORDS: Nanotechnology, Nanomaterials, Thermal performance, Environmental performance, Energy consumption

1. INTRODUCTION

There is currently a good range of commercialised nanomaterials designed to improve the environmental performance of buildings. Their performance is designed to respond to different priorities defined by the building construction industry's sustainability agenda, in which thermal control plays a major role. This research is focused on assessing the thermal performance of some of these nanomaterials. We understand that performance comes as a result of combining material properties and design. Departing from equal design solutions, can we rely on material properties alone to meet a targeted performance? In this regard, can nanomaterials outperform traditional materials?

To answer this question, we have designed a methodology to analyse and assess the thermal performance of a selection of nanomaterials. Some nanomaterials claim to have a positive input in the sustainable performance of buildings, but this performance has been only assessed as isolated individual materials by their manufacturers, and not as architectural solutions (assemblies/components) that form part of an applied design strategy. This research aims to investigate this gap in current knowledge in relation to the environmental performance of nanomaterials for their application in contemporary architecture. The research objectives of this study are: to analyse and assess the energy and environmental performance (thermal performance, energy consumption and CO2 emissions) and ecological profile (embodied energy and carbon) of a selection of nanomaterials for architecture. This short paper focuses on presenting our research methodology.

2. METHODOLOGY

As a first step, it was important to classify the collected information in an organized and efficient way, for which a database was developed (Figure1). This database would also allow us to classify all technical data related to nanomaterials and case studies, compare the different aspects of the environmental performance of these materials, and efficiently select a combination of materials to be used in our analysis, which would involve computer simulations and life cycle analysis.

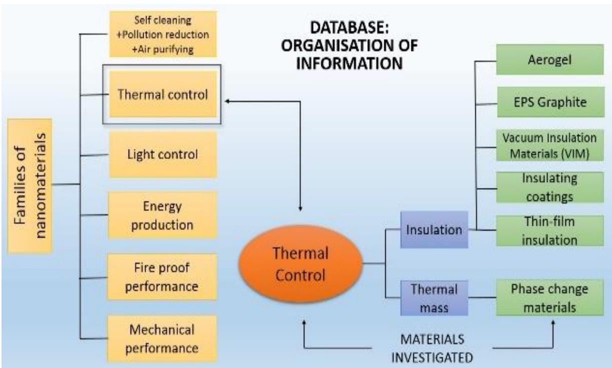

Figure 1 – Nanomaterials Families in Architecture

For our analysis we chose a Zero Carbon House for which we could get sufficient data, and change their material solutions using nanomaterials, simulate them, compare them, and extract conclusions. The Zero Carbon House (ZCH) in Birmingham (Figure2), has been thoroughly analysed and monitored, showing excellent energy performance and retrofitting design qualities. The main goal is to use this house as a departing model, changing its material assemblies using new ones that include as many nanomaterials as possible to convert it into a Nano house, then simulate the house in all its new material configurations, compare the results to its current real solutions, and lastly extract conclusions. For evaluating performance, we are using the environmental simulation software Design Builder.

Figure 2 – Zero Carbon House in Birmingham, Street view

Firstly, the house's thermal performance was simulated in its current state with the aim of validating our model, which effectively obtained the same results claimed by the designer. Secondly, it has been simulated with different nanomaterial assemblies, using either insulating nanomaterials or nanomaterials with high thermal mass capacity: Aerogel, Phase Change Materials (PCMs), Thin-film Insulation, Vacuum Insulation Materials (VIM), and Insulating Coating and Expanded Polystyrene Products (EPS Graphite) (Figure3). Critical factors in this analysis were: thickness, conductivity, specific heat, and density.

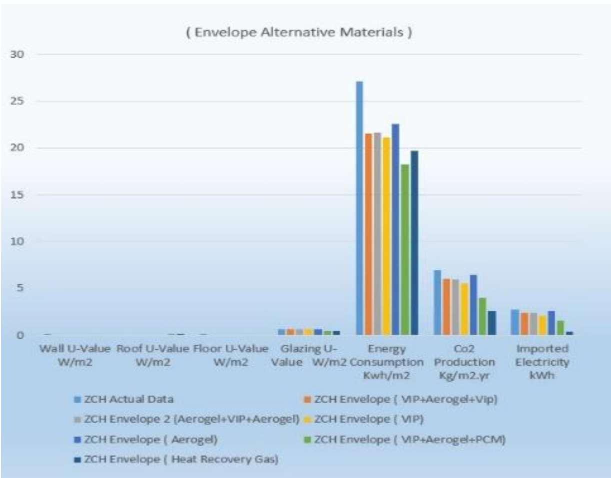

Figure 3 – Simulation results

Performance assessment considered heat loss and variations in internal temperature, energy efficiency, CO_2 emissions, and cost. Walls, roof, floors and windows were separately simulated for different construction details, the ones offering the best results were combined to generate the Nano house version, which was holistically simulated.

3. CONCLUSION

This paper focuses on assessing the use of nanomaterials in comparison to conventional sustainable solutions in architecture. Preliminary results show that the use of these emergent materials can effectively optimise the building's thermal performance in different aspects, getting the best results from Vacuum Insulation Panels. The use of nanomaterials improved the thermal and environmental performance of the analysed ZCH House, by reducing its energy consumption by 25% and its CO_2 emissions by 45%. The use of these materials opens new alternative routes for sustainable design strategies and a new array of specialised functions. We are currently working on the next phase in the study, which looks into developing the ecological profile of these materials (LCA), to assess their performance in connection with their environmental impact.

ACKNOWLEDGEMENTS

The authors would like to acknowledge the Iraqi Ministry of Higher Education and Scientific Research and the Middle Technical University in Baghdad for the scholarship given to the first author, and Iraqi Cultural Attaché in London for their effort in managing the scholarship. In addition, they acknowledge the University of Liverpool for their support.

REFERENCES

1.Bozsaky, D., 2016. Application of nanotechnology-based thermal insulation materials in building construction. *Slovak Journal of Civil Engineering,* 24(De Gruyter).

2.Halla Huws, L. J., 2014. *Birmingham zero carbon house - making it stay zero carbon through climate change.* Birmingham, Birmingham City University.

3.Jankovic, L., 2017. *Designing zero carbon buildings using dynamic simulation methods.* 2nd edition ed. San Diego: University of California.

4.Ledycker, s., 2008. *Nano materials in Architecture, Interior Architecture and Design.* Basel: Birkhauser.

5.Misra, M., 2011. The Elements of Architecture: Principles of Environmental Performance in Buildings. *International Journal of Environmental Studies,* 68(2), pp. 234-236.

6.W. Zhu, P. B. A. P., 2004. Application of nanotechnology in construction. *Materials and Structures/ Matériaux et Constructions,* October.Volume 37.