

# Graduation Plan

Master of Science Architecture, Urbanism & Building Sciences



## Graduation Plan: All tracks

The graduation plan consists of at least the following data/segments:

Personal information	
Name	Dimitra Mountaki
Student number	

Studio		
Name / Theme	Design Informatics	
Main mentor	Dr. Michela Turrin	Design Informatics
Second mentor	Dr. Martin Tenpierik	Climate Design, Building Physics
Argumentation of choice of the studio	The construction industry has been cautious about embracing technological solutions, bringing up challenges to dealing with the demand for new structures through innovative ways. Integrating design informatics, especially computational design, with climate design, integrating building physics, I am convinced that it may offer ways to speed up decision-making in the early design phase and provide optimal results.	

Graduation project	
Title of the graduation project	Computational Optimization of Hempcrete Integration: Improving Energy Performance and Minimizing Embodied Energy in a Variety of Building Types and Climates
Goal	
Location:	The project's goal is to use computational methods to generate architectural designs. Based on the available data, the concept will be applied to multiple sites.
The posed problem,	<p>Climate change is one of the main challenges for the human-kind right now. Greenhouse gases are gathered in the lower atmosphere layers, while the current global concentration of CO<sub>2</sub> has surpassed the normal amount in the atmosphere (Penuelas et al., 2020). As it mentioned in the background, almost 35% of the global energy consumption and 40% of the global carbon dioxide emissions are generated by the construction sector (United Nations Environment Programme, 2022).</p> <p>There have been several studies that focus on the buildings' energy consumption. Researches aimed to reduce the energy through the orientation (Kohansal et al., 2022) , the different climate (Schnieders et al., 2015), the future proof design (D'Agostino et al., 2022), by changing the façade (Bui et al., 2020a; Despoina Pouniou, 2019) and even more variables (Giouri, 2017; Wang, 2022). In the same way, there are papers that emphasize in innovative construction materials (Schiavoni</p>

	<p>et al., 2016; Yadav &amp; Agarwal, 2021) such as hempcrete. Recently, an interesting number of papers have been written for this material due to its negative carbon footprint (Pandian et al., 2023). However, the existing research is about the limited application of hempcrete in the building environment as the main material (Costantine et al., 2018a; Essaghouri et al., 2023a; Florentin et al., 2017a), or the optimization of the material itself (Agliata et al., 2019a; Bas et al., 2022a; Zemam et al., 2019a).</p> <p>The lack of computational methods that combines strategies to minimize operational energy and support preliminary designs with this material, result to uncertainty about its effectiveness comparing with the conventional materials. Meanwhile, it requires a corporation's time and funds to figure out which material is most suitable for a project.</p> <p>The current graduation project will emphasize on the lack of knowledge and of a systematic method, that support decision made in early design stages by using hempcrete as the main material, of high energy efficiency buildings, worldwide. Performance-driven architectural design is proven that has a significant influence on early decision-making within a design process (Shi &amp; Yang, 2013a). By shifting the attention towards the initial stages of a concept, the effect on both performance and cost of the design is more notable compared to delaying it(Trach et al., 2019a). The development of a computational approach will aim to supply architects and engineers with possible suggestions regarding the performance of various layout design options using hempcrete, contributing the early design phase.</p>
<p>research questions and</p>	<p>How can a computational method optimize hempcrete's integration in various type of buildings across diverse climates, with the objective to support preliminary designs that achieve high energy performance and minimize embodied energy?</p> <p><i>Sub-questions</i></p> <ul style="list-style-type: none"> <li>○ How does the composition of hempcrete (ratio of fibers, lime and water) affect the thermal conductivity and thus its integration in different climates?</li> <li>○ How does the thickness of hempcrete affect thermal and visual comfort in various types of buildings in different geographical regions, and what is the optimal thickness to achieve the optimum level of energy efficiency and visual comfort in each context?</li> <li>○ How can a computational workflow be used to establish a balance between energy efficiency and</li> </ul>

	<p>occupants comfort preferences, in hempcrete buildings?</p> <ul style="list-style-type: none"> <li>○ In which way can this workflow be evolved into a useful tool for reducing the required time during the first design stages and promote the use of hempcrete?</li> </ul>
<p>design assignment in which these results.</p>	<p>The general objective of the current thesis is to develop an efficient optimization workflow for energy-efficient hempcrete structures to be used in the initial phases of design, aiming to propose optimal designs for a variety of buildings and climates. Within this scope, quantitative variables will be applied via a multi-objective optimization process, to determine hempcrete's evaluation and optimization of several layout possibilities in terms of energy and comfort efficiency.</p> <p>The final product of this graduation topic is a computational optimization approach that enables supporting decision made in primary design phases to enhance the energy efficiency of buildings constructed with hempcrete. This approach can adapt to thermal and visual comfort without restrictions on climate conditions or building types.</p>

## Process

### Method description

The current graduation project's methodology and approach seek to address the lack of knowledge and of a structured approach that support performance-driven designs, while providing insights on the energy performance within a computational workflow. The process consists of multiple stages.

#### Research Framework

The preliminary phase includes an extensive review of existing literature in order to determine the problem, identify gaps in existing studies, and determine the thesis' aims and the research question.

#### Literature Review

The second part consists of a vast analysis of the literature, beginning with hempcrete's data, such as its thermal properties, its sustainable nature, and current applications. Following that, the emphasis is on the energy usage and current comfort requirements, which are essential for later modeling purposes. Climate data are also covered in the review, as well as methods for obtaining and validating future climate data. A significant part of this phase is dedicated to optimization, which includes investigating existing approaches linked to hempcrete as an

insulating material, present energy optimization tools, and performance-driven architectural design.

### **Simulation Implementation and Optimization**

The third step focuses on developing the framework of the simulation approach. A method is designed to assist the subsequent optimizing of designs using tools such as Grasshopper, as well as plugins such as Honeybee and ModeFrontier. To ensure efficiency, the developed approach is validated using DesignBuilder.

### **Design Proposal Collection and Evaluation**

In the fourth phase, the simulation functions on multiple proposed designs, using optimization techniques to determine ideal layouts integrating hempcrete walls. The last phase comprises gathering design options regarded as appropriate based on location and usage requirements, followed by an evaluation.

### **Discussion and Conclusion**

The research concludes with a discussion and conclusion. Furthermore, the report states prospective future improvements focusing on the practical application and evolution of the computational tool produced throughout this research.

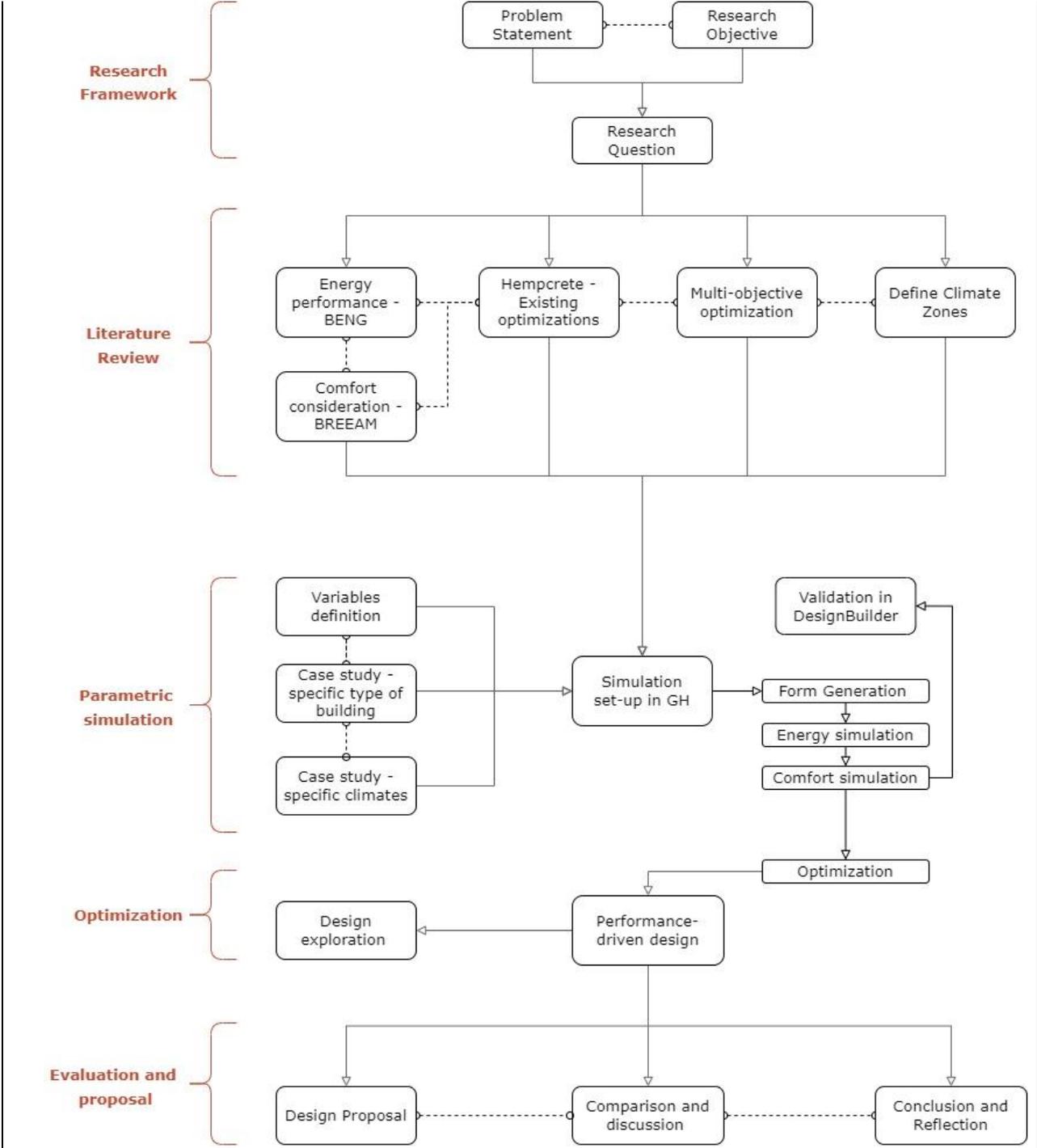


Figure 1: The research framework of the graduation topic to analyze the existing research and develop the new computational method to produce the designs.

## Literature and general practical references

The thesis builds on previous work in computational design, environmental standards, material science, design, and engineering. Key study fields include publications that explore experimental applications of hempcrete in a variety of regions, building categories, and specifications. It also goes into existing design and optimization applications, as well as a review of design principles defined by environmental requirements.

The complete reference list currently contains the following sources:

Agliata, R., Gianoglio, S., & Mollo, L. (2019a). Hemp-lime composite for buildings insulation: Material properties and regulatory framework. *Vitruvio*, 4(1), 47–57. <https://doi.org/10.4995/vitruvio-ijats.2019.11771>

Agliata, R., Gianoglio, S., & Mollo, L. (2019b). Hemp-lime composite for buildings insulation: Material properties and regulatory framework. *Vitruvio*, 4(1), 47–57. <https://doi.org/10.4995/vitruvio-ijats.2019.11771>

Ahlberg, J., Georges, E., & Norlen, M. (2014). *The potential of hemp buildings in different climates*. <http://www.teknat.uu.se/student>

Akpan, U. F., Akpan, G., & Akpan, G. E. (2012). The Contribution of Energy Consumption to Climate Change: A Feasible Policy Direction. *International Journal of Energy Economics and Policy*, 2(1), 21–33. [www.econjournals.com](http://www.econjournals.com)

Bana, A., & Jankovic, L. (2019). Reducing simulation performance gap from hempcrete buildings using multi objective optimization. *Building Simulation Conference Proceedings*, 1, 425–432. <https://doi.org/10.26868/25222708.2019.210914>

Bas, Y. J., Kamal, I., Muhsin, H., Najat, C., & Syamand, M. (2022a). Hempcrete a Renewable Material for Green Building: Manufacturing and Properties Optimization. *AIP Conference Proceedings*, 2660. <https://doi.org/10.1063/5.0108734>

Bas, Y. J., Kamal, I., Muhsin, H., Najat, C., & Syamand, M. (2022b). Hempcrete a Renewable Material for Green Building: Manufacturing and Properties Optimization. *AIP Conference Proceedings*, 2660. <https://doi.org/10.1063/5.0108734>

Bui, D. K., Nguyen, T. N., Ghazlan, A., Ngo, N. T., & Ngo, T. D. (2020a). Enhancing building energy efficiency by adaptive façade: A computational optimization approach. *Applied Energy*, 265. <https://doi.org/10.1016/j.apenergy.2020.114797>

Bui, D. K., Nguyen, T. N., Ghazlan, A., Ngo, N. T., & Ngo, T. D. (2020b). Enhancing building energy efficiency by adaptive façade: A computational optimization approach. *Applied Energy*, 265. <https://doi.org/10.1016/j.apenergy.2020.114797>

Costantine, G., Maalouf, C., Moussa, T., & Polidori, G. (2018a). Experimental and numerical investigations of thermal performance of a Hemp Lime external building insulation. *Building and Environment*, 131, 140–153. <https://doi.org/10.1016/j.buildenv.2017.12.037>

- Costantine, G., Maalouf, C., Moussa, T., & Polidori, G. (2018b). Experimental and numerical investigations of thermal performance of a Hemp Lime external building insulation. *Building and Environment*, *131*, 140–153. <https://doi.org/10.1016/j.buildenv.2017.12.037>
- D'Agostino, D., Parker, D., Epifani, I., Crawley, D., & Lawrie, L. (2022). How will future climate impact the design and performance of nearly zero energy buildings (NZEBs)? *Energy*, *240*. <https://doi.org/10.1016/j.energy.2021.122479>
- Department of Economic and Social Affairs. (2022). *World Population Prospects 2022: Summary of Results*.
- Despoina Pouniou. (2019). *COMPUTATIONAL OPTIMIZATION FOR THE FACADE DESIGN OF A NEARLY ZERO-ENERGY HIGH-RISE OFFICE BUILDING IN THE TEMPERATE CLIMATE DESPOINA POUNIOU COMPUTATIONAL OPTIMIZATION FOR THE FACADE DESIGN OF A NEARLY ZERO-ENERGY HIGH-RISE OFFICE BUILDING IN THE TEMPERATE CLIMATE*.
- Dlimi, M., Iken, O., Agounoun, R., Zoubir, A., Kadiri, I., & Sbai, K. (2019). Energy performance and thickness optimization of hemp wool insulation and air cavity layers integrated in Moroccan building walls'. *Sustainable Production and Consumption*, *20*, 273–288. <https://doi.org/10.1016/j.spc.2019.07.008>
- Essaghouri, L., Mao, R., & Li, X. (2023a). Environmental benefits of using hempcrete walls in residential construction: An LCA-based comparative case study in Morocco. *Environmental Impact Assessment Review*, *100*. <https://doi.org/10.1016/j.eiar.2023.107085>
- Essaghouri, L., Mao, R., & Li, X. (2023b). Environmental benefits of using hempcrete walls in residential construction: An LCA-based comparative case study in Morocco. *Environmental Impact Assessment Review*, *100*. <https://doi.org/10.1016/j.eiar.2023.107085>
- Florentin, Y., Pearlmutter, D., Givoni, B., & Gal, E. (2017a). A life-cycle energy and carbon analysis of hemp-lime bio-composite building materials. *Energy and Buildings*, *156*, 293–305. <https://doi.org/10.1016/j.enbuild.2017.09.097>
- Florentin, Y., Pearlmutter, D., Givoni, B., & Gal, E. (2017b). A life-cycle energy and carbon analysis of hemp-lime bio-composite building materials. *Energy and Buildings*, *156*, 293–305. <https://doi.org/10.1016/j.enbuild.2017.09.097>
- Friess, W. A., Rakhshan, K., & Davis, M. P. (2017). A global survey of adverse energetic effects of increased wall insulation in office buildings: degree day and climate zone indicators. *Energy Efficiency*, *10*(1), 97–116. <https://doi.org/10.1007/s12053-016-9441-z>
- Fumagalli, A. (n.d.). *Energy Space Layout Designing space layout with optimised energy performance*.
- Giouri, D. (2017a). *ZERO ENERGY POTENTIAL OF A HIGH RISE OFFICE BUILDING IN A MEDITERRANEAN CLIMATE*. Delft University of Technology.
- Giouri, D. (2017b). *ZERO ENERGY POTENTIAL OF A HIGH RISE OFFICE BUILDING IN A MEDITERRANEAN CLIMATE*. Delft University of Technology.

Hadji, F. El. (2019). *Design parameter guidelines for purely passive cooling buildings in Tropical regions*. <http://repository.tudelft.nl/>.

Idowu, A., Ohikhuare, O. M., & Chowdhury, M. A. (2023). Does industrialization trigger carbon emissions through energy consumption? Evidence from OPEC countries and high industrialised countries. *Quantitative Finance and Economics*, 7(1), 165–186. <https://doi.org/10.3934/QFE.2023009>

Jere, K. (2018). *Thermal Properties of Hempcrete, a Case Study*. Helsinki Metropolia university of Applied Sciences.

Kohansal, M. E., Akaf, H. R., Gholami, J., & Moshari, S. (2022). Investigating the simultaneous effects of building orientation and thermal insulation on heating and cooling loads in different climate zones. *Architectural Engineering and Design Management*, 18(4), 410–433. <https://doi.org/10.1080/17452007.2021.1901220>

Li, K., & Lin, B. (2015). Impacts of urbanization and industrialization on energy consumption/CO2 emissions: Does the level of development matter? In *Renewable and Sustainable Energy Reviews* (Vol. 52, pp. 1107–1122). Elsevier Ltd. <https://doi.org/10.1016/j.rser.2015.07.185>

Moussa, T., Maalouf, C., Ingrao, C., Scrucca, F., Costantine, G., & Asdrubali, F. (2018). Bio-based and recycled-waste materials in buildings: A study of energy performance of hemp-lime concrete and recycled-polyethylene terephthalate façades for office facilities in France and Italy. *Science and Technology for the Built Environment*, 24(5), 492–501. <https://doi.org/10.1080/23744731.2018.1438664>

Pandian, N. G., Venugopal, Y., Shah, A., & Oli, A. (2023). Zero Carbon Hempcrete Construction – An Overview. *AIP Conference Proceedings*, 2766. <https://doi.org/10.1063/5.0140063>

Schiavoni, S., D'Alessandro, F., Bianchi, F., & Asdrubali, F. (2016). Insulation materials for the building sector: A review and comparative analysis. In *Renewable and Sustainable Energy Reviews* (Vol. 62, pp. 988–1011). Elsevier Ltd. <https://doi.org/10.1016/j.rser.2016.05.045>

Schnieders, J., Feist, W., & Rongen, L. (2015). Passive Houses for different climate zones. *Energy and Buildings*, 105, 71–87. <https://doi.org/10.1016/j.enbuild.2015.07.032>

Shang, Y., & Tariku, F. (2021). Hempcrete building performance in mild and cold climates: Integrated analysis of carbon footprint, energy, and indoor thermal and moisture buffering. *Building and Environment*, 206. <https://doi.org/10.1016/j.buildenv.2021.108377>

Shi, X., & Yang, W. (2013a). Performance-driven architectural design and optimization technique from a perspective of architects. *Automation in Construction*, 32, 125–135. <https://doi.org/10.1016/j.autcon.2013.01.015>

Shi, X., & Yang, W. (2013b). Performance-driven architectural design and optimization technique from a perspective of architects. *Automation in Construction*, 32, 125–135. <https://doi.org/10.1016/j.autcon.2013.01.015>

Technology, M. B., Supervisor, G., & Christodoulou, A. (2019a). *COMPUTATIONAL OPTIMIZATION FOR THE FACADE DESIGN OF A NEARLY ZERO-ENERGY HIGH-RISE OFFICE BUILDING IN THE TEMPERATE CLIMATE DESPOINA POUNIOU COMPUTATIONAL OPTIMIZATION FOR THE FACADE DESIGN OF A NEARLY ZERO-ENERGY HIGH-RISE OFFICE BUILDING IN THE TEMPERATE CLIMATE DESPOINA POUNIOU* 4748298.

Technology, M. B., Supervisor, G., & Christodoulou, A. (2019b). *COMPUTATIONAL OPTIMIZATION FOR THE FACADE DESIGN OF A NEARLY ZERO-ENERGY HIGH-RISE OFFICE BUILDING IN THE TEMPERATE CLIMATE DESPOINA POUNIOU COMPUTATIONAL OPTIMIZATION FOR THE FACADE DESIGN OF A NEARLY ZERO-ENERGY HIGH-RISE OFFICE BUILDING IN THE TEMPERATE CLIMATE DESPOINA POUNIOU* 4748298.

Trach, R., Połowski, M., & Petro, H. (2019a). Modelling of Efficiency Evaluation of Traditional Project Delivery Methods and Integrated Project Delivery (IPD). *IOP Conference Series: Materials Science and Engineering*, 471, 112043. <https://doi.org/10.1088/1757-899X/471/11/112043>

Trach, R., Połowski, M., & Petro, H. (2019b). Modelling of Efficiency Evaluation of Traditional Project Delivery Methods and Integrated Project Delivery (IPD). *IOP Conference Series: Materials Science and Engineering*, 471, 112043. <https://doi.org/10.1088/1757-899X/471/11/112043>

United Nations Environment Programme. (2022). *GLOBAL STATUS REPORT FOR BUILDINGS AND CONSTRUCTION*. [www.globalabc.org](http://www.globalabc.org).

Vontetsianou, A. (2023). *THE EFFECTIVENESS OF HEMPCRETE IN THE REDUCTION OF ENVIRONMENTAL AND FINANCIAL COSTS OF RESIDENCES*. Delft University of Technology.

Wadanambi, R. T., Wandana, L. S., Chathumini, K. K. G. L., Dassanayake, N. P., Preethika, D. D. P., & Arachchige, U. S. P. R. (2020). The effects of industrialization on climate change. *JOURNAL OF RESEARCH TECHNOLOGY AND ENGINEERING*, 1.

Wang, K.-L. (2022a). *Building Design Approaches and Performance Under Predicted Climate Conditions*.

Wang, K.-L. (2022b). *Building Design Approaches and Performance Under Predicted Climate Conditions*.

Wang, S., Yan, C., & Xiao, F. (2012). Quantitative energy performance assessment methods for existing buildings. In *Energy and Buildings* (Vol. 55, pp. 873–888). <https://doi.org/10.1016/j.enbuild.2012.08.037>

Yadav, M., & Agarwal, M. (2021). Biobased building materials for sustainable future: An overview. *Materials Today: Proceedings*, 43, 2895–2902. <https://doi.org/10.1016/j.matpr.2021.01.165>

Zemam, S. K., Resan, S. F., & Abed, M. S. (2019a). Structural Characteristics of Developed Sustainable Lime-Straw Composite. *Civil Engineering Journal (Iran)*, 5(12), 2587–2597. <https://doi.org/10.28991/cej-2019-03091435>

Zemam, S. K., Resan, S. F., & Abed, M. S. (2019b). Structural Characteristics of Developed Sustainable Lime-Straw Composite. *Civil Engineering Journal (Iran)*, 5(12), 2587–2597.  
<https://doi.org/10.28991/cej-2019-03091435>

## Reflection

1. What is the relation between your graduation (project) topic, the studio topic (if applicable), your master track (A,U,BT,LA,MBE), and your master programme (MSc AUBS)?

The MSc AUBS program promotes innovation in architecture and engineering, which is similar to the topic of my thesis on innovative alternatives to the design process. The building technology program, in particular, emphasizes the integration of design and technical disciplines, encouraging a multi-disciplinary approach. Therefore, my thesis takes an integrative approach by connecting skills from climate design, engineering, and computational design. This distinctive combination of knowledge is essential for my topic, which requires an in-depth understanding of the built environment and focuses on informatics research. By combining these specialties, I can analyze a topic related to design and engineering from a new perspective.

2. What is the relevance of your graduation work in the larger social, professional and scientific framework.

The current research topic of computational design within the architecture, engineering, and construction industries has been largely controlled by private firms, resulting in a shortage of openly accessible data regarding the automation of early building design phases. These gaps present the potential to improve industry expertise and simplify the design process, making design more accessible to a wider audience. This thesis seeks to contribute to the narrowing of this knowledge gap.

The study in this thesis focuses on establishing ways for automating the design process with a bio-aggregate material, thereby extending the potential of existing generative design tools. In the future, these generative design tools could offer not only massing, site layouts, and 3D plans but also ideas for complex 3D building systems. This study is a fundamental step, opening the way for future research on bio-based materials and their optimal integration into the design process.