Graduation Plan

Master of Science Architecture, Urbanism & Building Sciences

Graduation Plan: All tracks

Submit your Graduation Plan to the Board of Examiners (Examencommissie-BK@tudelft.nl), Mentors and Delegate of the Board of Examiners one week before P2 at the latest.

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

Personal information	
Name	Athanasios Rodiftsis
Student number	4943295
Telephone number	
Private e-mail address	

Studio		
Name / Theme	[Building Technology Sustainable Design Graduation Studio / Design Informatics and Structural Design & Mechanics]	
Main mentor	Dr. S. Asut	Design Informatics
Second mentor	Dr.ir. F.A. Veer	Structural Design & Mechanics
Argumentation of choice of the studio	The building industry is increasingly adopting innovative manufacturing technologies, such as additive manufacturing in construction. This can lead to significant changes in the construction pipeline, as well as to a reevaluation of construction materials. Building with earth, while having clay as the main binder has the potential to become an alternative to building with concrete, which is responsible for the big environmental impact of construction industry. TiSD annotation This thesis will also be part of the TiSD annotation. My interest in concepts such as sustainability and circularity led me to structure my electives with as many credits related to sustainable development as I could. Sustainability is central to the theme of the project. Through efficient use of energy and resources, the impact of construction on the environment can be minimized.	

Graduation project	
Title of the graduation project	Robotic Additive Manufacturing (RAM) of an earthen shell structure: structural optimization through computational design
Goal	
Location:	Greece
The posed problem,	The energy consumption of construction industry amounts to 40% of the total energy used in most countries. In addition, carbon emissions of concrete amount to 8% of global emissions. Through the traditional way of construction, buildings end up as construction waste, as their lifecycle is not considered.

	Moreover, their design is sub-optimal as high performance criteria are hard to implement. 3D printing in construction using earth can address these issues through highly efficient performative design with an environmentally friendly, recyclable material. Structural optimization will ensure stability with minimal use of material.
research questions and	The main research objective is to contribute to innovation in construction by developing a pipeline for 3D printing in construction using earth. The main research question is: How to develop a design to fabrication workflow for a structurally optimized shell towards robotic additive manufacturing by clay binder? The sub research questions are: • What are the design and performance criteria involved in designing a robotically 3D printed component? • What are the advantages and limitations of using clay? What is the best mixture in this setup? • What is the effect of infill / layer height / fibers / kiln / extrusion speed / drying time / geometry in the mechanical properties of the component? • What is the projected environmental impact of the proposed construction?
Design assignment in which these result.	The research question leads to the development of an integrated workflow from design to production. The design assignment will be a proof of concept of the proposed workflow: • Structurally optimized earthen shell structure created using entirely reusable, recyclable materials sourced from the local terrain

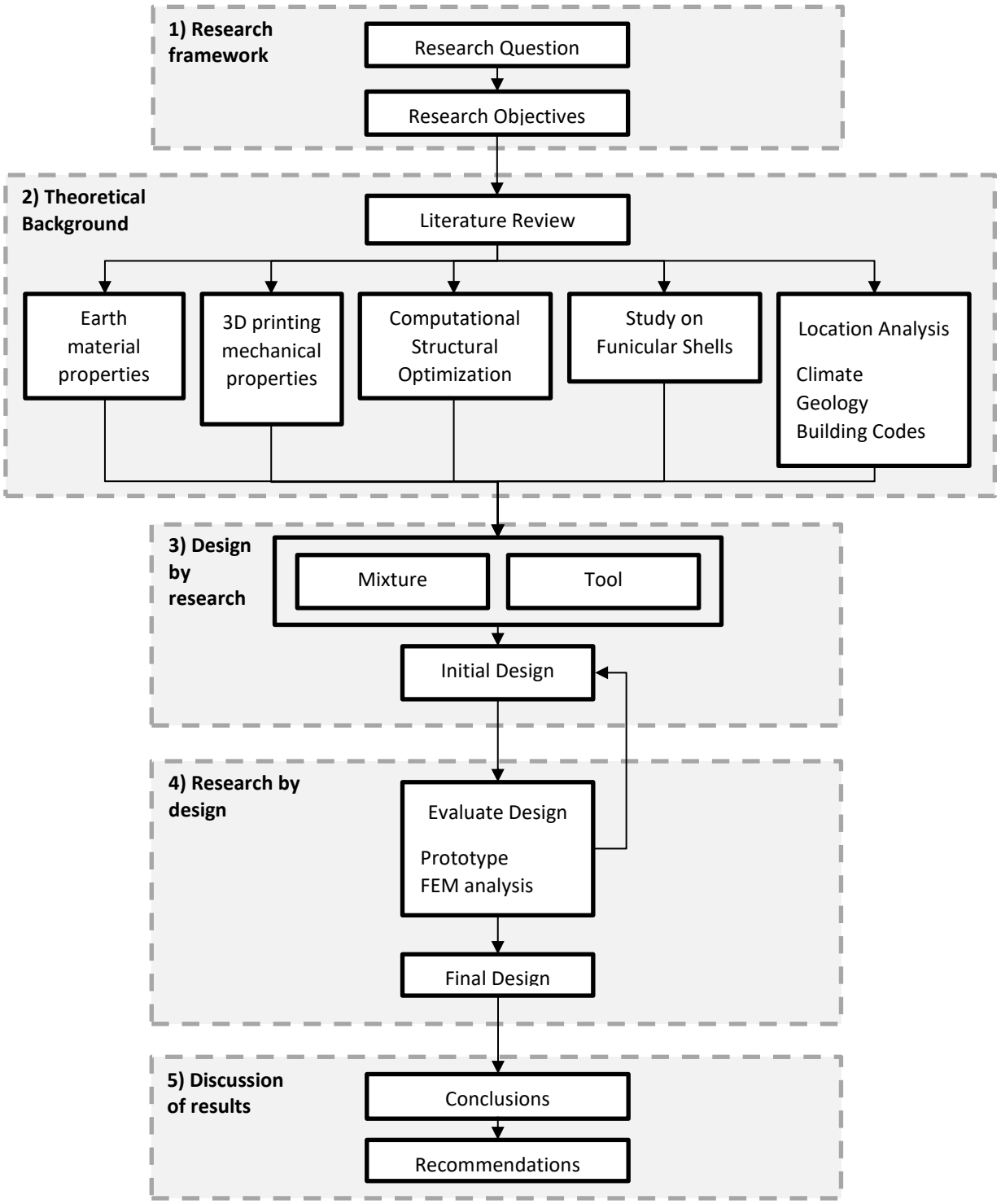
[This should be formulated in such a way that the graduation project can answer these questions.
The definition of the problem has to be significant to a clearly defined area of research and design.]

Process

Method description

The method follows the steps as illustrated in the diagram:

1) Research Framework
2) Literature Review
3) Design by Research
4) Research by Design
5) Discussion of results



Literature and general practical preference

The main research avenues are:

- Material scope exploration with emphasis on mechanical properties
- Robotic manufacturing process and its effect on mechanical properties
- Computational Design for Structural Optimization
- Funicular shell design
- Location Analysis in terms of climate, geology and building codes

Literature

[1] Bommes, D., Zimmer, H., Kobbelt, L. (2009). Mixed-integer quadrangulation. ACM Transactions on Graphics (TOG) 28, 3, 77.

[2] De Wit, S. (2016), Parametric Segmental Timber Shell Structures Using Form-Finding: In combination with structural analysis and digital fabrication, Eindhoven, The Netherlands

[3] Mariette Moevus, Yves Jorand, Christian Olagnon, Sandrine Maximilien, Romain Anger, et al.. Earthen construction: an increase of the mechanical strength by optimizing the dispersion of the binder phase. Materials and Structures, Springer Verlag, 2015, pp.1--14. ⟨10.1617/s11527-015-0595-5⟩. ⟨hal-01159955⟩
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[5] Ngo, T. D., Kashani, A., Imbalzano, G., Nguyen, K. T. Q., & Hui, D. (2018, February 13). Additive manufacturing (3D printing): A review of materials, methods, applications and challenges. Retrieved from https://www.sciencedirect.com/science/article/pii/S1359836817342944?via=ihub.
[6] O.O. Akinkurolere, Cangru Jiang, A.T. Oyediran, O.I. Dele- Salawu and A.K. Elensinnla, 2006. Engineering Properties of Cob as a Building Material. Journal of Applied Sciences, 6: 1882-1885.
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[12] REEVES, G. M, SIMS, I. & CRIPPS, J. C. (eds) 2006. Clay Materials Used in Construction. Geological Society, London, En~ineerin~ Geology Special Publication, 21.
[13] Srivastana, P. K., Simant, & Shuckla, S. (2017). Structural Optimization Methods: A General Review. IJIRSET, 6(9).
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Reference projects
TECLA (WASP)

GAIA (WASP)
Architecture of Continuity: from materiality to environment (iaac)

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 main themes of the topic are:

- Robotic Additive Manufacturing (RAM)
- Structural Design optimization
- Sustainable materials innovation

Therefore, the topic merges Design Informatics and Structural Design & Mechanics, while using an environmentally friendly material, through the prism of the Sustainable Design Graduation studio.

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

Social

The graduation work introduces a construction process with low environmental impact and reduced CO2 emissions. It achieves these through a reduction in transport operations and costs by the employment of natural material resources, providing an alternative to concrete. On a broader sense, the method promotes the capitalization of local workforce and resources for construction, since no advanced training is needed to utilize the tools and the materials are decided based on availability. This can assist in the democratization of production technologies, through an open-source construction paradigm and a reduction in the cost of construction. As 3D printing in construction is an emerging concept, the project ultimately contributes to the expansion of human knowledge.

Professional

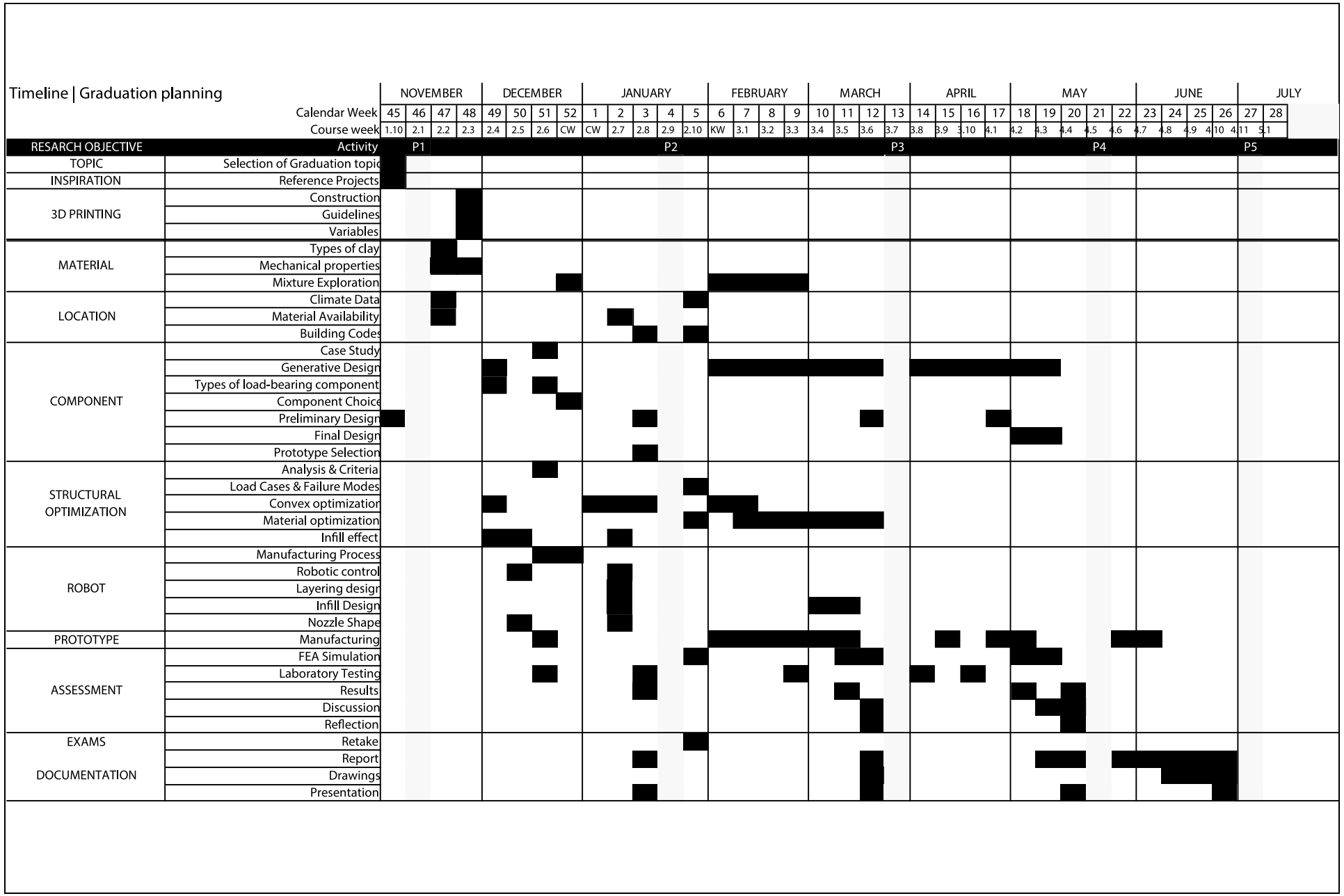
In the professional framework, the project achieves high construction performances, through the integration of computational optimization in the design and manufacturing process. This can contribute not only in mistake reduction but also in the integration of additional functions during printing, such as structural optimization, thermal insulation, natural ventilation and secondary working avoidance.

Scientific

In the scientific realm, the work adopts novel evaluation methods through the digitization of the construction process, BIM, file-to-factory. 3D printing offers the replicability of the architectural project, with high-quality standards.
Realization of non-standard architectural geometries and material saving through algorithmic design

Time planning

The time planning is shown by the table on the next page


Timeline | Graduation planning
NOVEMBER
DECEMBER
JANUARY
FEBRUARY
MARCH
APRIL
MAY
JUNE
JULY
Calendar Week
45 46 47 48 49 50 51 52 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28
Course week
1.10 2.1 2.2 2.3 2.4 2.5 2.6 CW CW 2.7 2.8 2.9 2.10 KW 3.1 3.2 3.3 3.4 3.5 3.6 3.7 3.8 3.9 3.10 4.1 4.2 4.3 4.4 4.5 4.6 4.7 4.8 4.9 4.10 4.11 5.1
RESARCH OBJECTIVE
Activity
P1
P2
P3
P4
P5
TOPIC
Selection of Graduation topic
INSPIRATION
Reference Projects
3D PRINTING
Construction
Guidelines
Variables
MATERIAL
Types of clay
Mechanical properties
Mixture Exploration
LOCATION
Climate Data
Material Availability
Building Codes
COMPONENT
Case Study
Generative Design
Types of load-bearing component
Component Choice
Preliminary Design
Final Design
Prototype Selection
STRUCTURAL OPTIMIZATION
Analysis & Criteria
Load Cases & Failure Modes
Convex optimization
Material optimization
Infill effect
ROBOT
Manufacturing Process
Robotic control
Layering design
Infill Design
Nozzle Shape
PROTOTYPE
Manufacturing
ASSESSMENT
FEA Simulation
Laboratory Testing
Results
Discussion
Reflection
EXAMS
Retake
DOCUMENTATION
Report
Drawings
Presentation