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	Fawzi Bata
Student number	5117739

Studio		
Name / Theme	Building Technology Sustainable Design Graduation Studio/ Design Informatics and Material Science	
Main mentor	Dr. Serdar Asut	Design Informatics
Second mentor	Dr. ir. Fred Veer	Material Science
Argumentation of choice of the studio	Mass customization is inherent to the process of additive manufacturing, which in combination with using earth found on site as a medium for printing, could make it a viable approach to constructing shelters that would meet individual refugee family needs. The studio choice combines design informatics on one hand, which relates to the creation of a generative design tool using computational design methods, along with the study of additive manufacturing and robotic 3D printing in the context of building construction, and material science on the other hand which relates to the study of earth found on-site as a printing material along with its properties and possible additives to create a mixture for printable structures.	

Graduation project	
Title of the graduation project	Digital Earthen Shelters: Additively Manufacturing Mass Customized Refugee Shelters Using On-Site Earthen Materials
Goal	
Location:	The primary case studies are Zaatari & Azraq refugee camps in Jordan
The posed problem,	Current refugee shelters are being made with a transitional temporary use in mind and in a manner that does not take individual family needs into account but rather have a one-size-fits-all design. The shelters are also subsidized by governments which in many cases do

	not have the resources required to provide anything but shelters that only provide immediate protection, and using materials that are transported into the site with minimal regard to circularity and longevity. This calls for a mass-customizable and circular dwelling solution that caters to individual refugee family needs. Many developments are being made regarding 3D printing structures with earth, however mass customizing these structures has not yet been explored in depth although it is inherent to additive manufacturing techniques.
research questions and	Main Research Question: How can additive manufacturing be employed in creating mass-customized refugee shelters using on-site earthen materials? Sub-Questions: Material What are earthen materials? How are they used in construction? What is the composition of earth found on site in the cases of Zatari and Azraq refugee camps? What additives need to be incorporated into the material mixture in order to create printable structures using earth? How do the different earth mixtures perform in terms of extrudability, shrinkage, cracking, … etc.? Shelter Design What are the user needs of refugee families for shelter designs? How can shelters be designed to accommodate user needs? How can user needs be translated into mass-customized designs using computational methods? How can these designs be optimized for fabrication using additive manufacturing?

	Fabrication Process Which printing methods and machines allow for quick deployment and low cost execution of the proposed shelter designs? What does the printing process look like from extracting the material until producing the prototype?
design assignment in which these result.	- Develop earth testing toolkit to be used on-site for along with a manual for mixture design - Develop a generative dwelling design tool for refugee shelters that can produce customized designs in-situ and create printing toolpaths. - Produce 1:20 prototypes for iterations generated by design tool - Design and simulate a robotic workflow for additive manufacturing of shelters - Produce 1:1 prototype for small part of example dwelling wall as a proof of concept using earth mixture

Process

Method description

Experiments:
Experiments will be done by replicating the earth composition collected from the chosen sites, and then testing different mixture possibilities. The experiments will be conducted to test for mixture printability.

Literature Review:
A literature review is required to investigate the material properties of earth as well as for additives to create a printable mixture. The literature review will also cover a state-of-the art analysis of current additive manufacturing techniques in construction as well as precedents in 3d printing using earth. It will also aid in understanding refugee needs in order to create mass-customized designs based on those needs.

Research by Design:
A design tool will be developed computationally for generating refugee shelter designs based on individual needs from a library of designs/ a kit-of-parts.

Prototyping:
In order to verify the printability, robotic simulations, and the robotic workflow design, prototyping using earth mixtures in a 1:1 scale will be explored. A smaller scale (around 1:20) of prototypes will be produced to test the iterations of dwelling designs produced by the generative design tool that will be developed.

Literature and general practical preference

References:

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Venturi, T., Turrin, M., Setaki, F., Veer, F., Pronk, A., Teuffel, P., . . . Vorstermans, R. (2019). Terra–Ink: Additive Earth Manufacturing for Emergency Architecture. SPOOL, 6, 41-46.

Volhard, F. (2016). Light Earth Building : A Handbook for Building with Wood and Earth. Basel: Birkhauser Verlag GmbH.

Precedent Projects:
TECLA 3D – WASP
GAIA - WASP
Mud Frontiers – Ronald Rael
Potterware – Ronald Rael
OTF – IAAC
Tera – AI Spacefactory
Terra Ink – Tommaso Venturi

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)?
   This research aims to utilize tools from the fields of design informatics and material science in order to create mass-customized refugee shelters. This in a way bridges the gap between architecture and engineering in using robotics, material mixtures, and computational tools in order to design, prototype, and construct functional refugee dwellings which is very much at the core of what building technology is about. This in turn also fits into the broader fields of

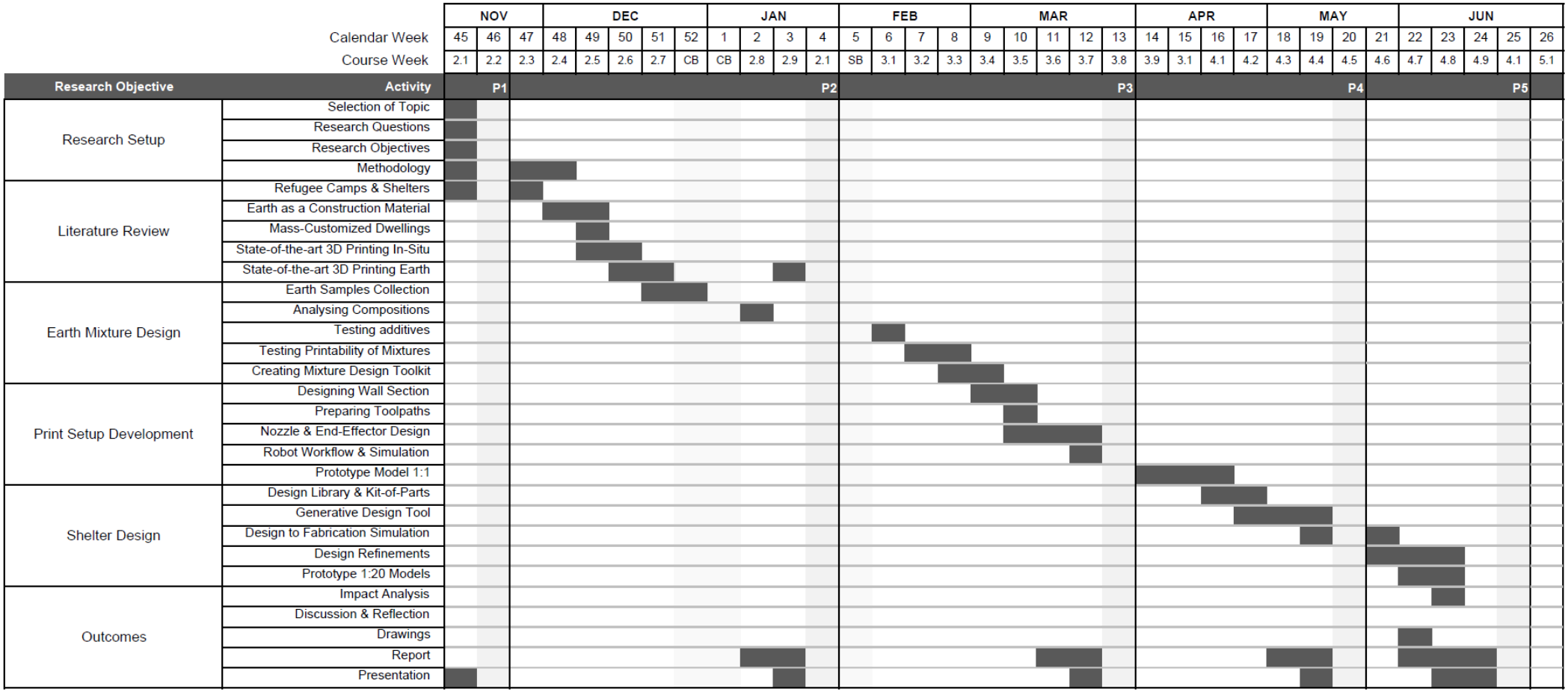
architecture, urbanism, and building sciences as it concerns the spatial design and fabrication of dwellings in the context of refugees and refugee camps which themselves are becoming urban settings.

2. What is the relevance of your graduation work in the larger social, professional and scientific framework?
   Social Relevance:
   The social component is central to this research as it concerns the current state of refugee sheltering and livelihood. Refugee numbers are unfortunately rapidly increasing in recent years due to humanitarian crises globally with a need for adequate and less temporary sheltering solutions that meet their individual needs.

   Scientific Relevance:
   Additive manufacturing in the field of construction is an emerging technology with new developments being constantly made as we transition into a more digital workflow. Sustainability and circularity are also present in this research through additively manufacturing on-site earthen materials which are biodegradable, require minimal transport, and require minimal processing which results in constructions with minimal embodied energy. The process also employs advanced robotic fabrication techniques to achieve the envisioned structures.

Time Planning

The following page shows the proposed work plan and phasing of the thesis


NOV
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Calendar Week
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Course Week
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Research Objective
Activity
P1
P2
P3
P4
P5
Research Setup
Selection of Topic
Research Questions
Research Objectives
Methodology
Literature Review
Refugee Camps & Shelters
Earth as a Construction Material
Mass-Customized Dwellings
State-of-the-art 3D Printing In-Situ
State-of-the-art 3D Printing Earth
Earth Mixture Design
Earth Samples Collection
Analysing Compositions
Testing additives
Testing Printability of Mixtures
Creating Mixture Design Toolkit
Print Setup Development
Designing Wall Section
Preparing Toolpaths
Nozzle & End-Effector Design
Robot Workflow & Simulation
Prototype Model 1:1
Shelter Design
Design Library & Kit-of-Parts
Generative Design Tool
Design to Fabrication Simulation
Design Refinements
Prototype 1:20 Models
Outcomes
Impact Analysis
Discussion & Reflection
Drawings
Report
Presentation