EARTHY: Generative Design for Earth and Masonry Architecture

Course Information: AR3B011–MSc3 Design Studio, First Quarter (2020-2021), ECTS: 15

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Consultations	Strictly during class hours, emails are only provided for decorative purposes ☺

Introduction

EARTHY is a master's level design studio with the aim of designing and engineering earthy buildings, in particular adobe buildings, intended for mid-term accommodation of displaced communities. Our goal is to design buildings that can be ideally built by their prospective inhabitants. Earthy buildings are virtually 100% recyclable and, compared to tents, they offer much more comfort. The use of earthen materials necessitates the knowledge of complex geometry e.g. in designing and technical drawing of vaults, domes and arches in optimal shapes. The focus of the course is on the relations of materials, shapes, and structures, explored computationally. Automated construction design and generation of assembly instructions are extra challenges to be tackled via computation. Read more about EARTHY here. See exemplary results of last year.

Learning goals

After finishing this course, the student is expected to be able:

- *to analyse the urban context, social-spatial structure, and vernacular traditions and develop an idea and a concept for the design responding to the context.*
- *to computationally design, utilize algorithms and underpin the architectural configuration of a settlement suitable for mass-customization in a circular construction process with low-cost materials, local labour, and low-tech construction techniques.*
- *to optimize complex geometric shapes for a desired structural performance, given a local material and functional requirements.*

Design Challenge

You are requested to design for betterment of a district of the Al Zaatari Refugee Camp in Jordan. The course is prepared for maximum 40 students working in six to eight groups of three to five students. The whole class is supposed to propose one Master Plan (Configuration) and a set of Urban Design Guidelines for a displaced-community, plan, and design communal buildings (proposed by groups) and dwellings. In short, there will be at least six sorts of buildings to be configured and designed, each of which is assigned to a single group. The entire class is responsible for the configuration of [one district of] the site.

Disclaimer

This is not a contract. This document is only made for informative purposes. No rights can be derived from this document. This course is research-oriented and as such, it is inherently experimental. We might deviate from the path described here if/when deemed necessary, observing the class dynamics.

Syllabus

After completing this course, the student is supposed to have gained 1) knowledge, 2) insight, and 3) skill on the use mathematical and computational principles, facts, conventions, and methods/algorithms in the context of designing an earthy settlement. By collaboratively working on 3D Procedural Models, Finite Element Analyses, Simulations, the students will be able to configure, design, and construct a settlement for displaced communities (e.g. refugees/ victims of natural disasters).

Theory

The subjects taught in this course are:

- *Linear Algebra, Calculus and Differential Geometry*
- *Geometry, Topology, and Graph Theory*
- *Computer Graphics (Boundary Representations and Raster Representations)*
- *Finite Element Analysis*
- *[Optional] Programming in Python and/or C#*
- *Material Science of Earth, Material Combinations*
- *Structural Design with Earth*
- *Earth Architecture & Architectural Configuration (a.k.a. space planning)*

Practice

The Earthy Studio is focused on devising computational methods, techniques and tools for analysis, synthesis, shape-generation, and optimization in:

- *Configuring: planning the arrangement of a settlement for a displaced community considering accessibility of amenities, and functional layout of communal/public buildings;*
- *Shaping: devising the 3D shape of the buildings based on their functional configuration, climatic functionality, and structural performance;*
- *Structuring: designing the construction process of an earth building for a zero-waste circular construction process*

Learning Path

The course suggests the following course of activities:

1) ***Planning:*** *a master plan for the site is produced by the whole class by super imposing multiple spatial analyses and ideas for improvements;*
2) ***Configuring:*** *each group composes a programme of requirement consistent with the master plan and an idea for the building with societal added value; specifies the intended user experience of the building in terms of a graph (bubble-chart) articulating the connections between the 'floor spaces'; and proposes a 3D layout based on this bubble chart.*
3) ***Shaping:*** *given the 3D configuration of floor spaces and their intended heights, the group is to propose a basic tessellation of the 'ceiling spaces' into a mesh, dynamically relax that mesh to get an idealised shell structure geometry, and propose a topological system of masonry ceiling structures to function as a spatial structure in accordance with the idealized structure.*
4) ***Structuring:*** *given the found form in the previous step and the proposed tessellation, the group is to validate the discrete spatial structure consisting of blocks to ensure that it is constructible, structurally sound in the sense of being a compression-only structure, and safe during and after construction.*

Study Hours

The 15ECTS credits correspond to 15 times 28 hours, i.e. a total of 420 hours of study/workload, which is equal to an average of 42 hours per week. Therefore, it is advisable not to pick other courses in parallel to this course. A third of these hours will be dedicated to supervised workshops, lectures (contact hours) and evaluations. In the workshop hours, we shall monitor and consult the progress of computational design process focusing on a set of thematic assignments on configuring, shaping, and structuring earthy settlements. The lectures are interactive. The students are supposed to spend a minimum of 280 hours on their own (self-study). Here is a specification of hours:

32(lectures)+16(labs)+48(consultations)+32(technical support)+280(self-study)+12 (evaluation)= 420(hours)=15ECTSx28(hours)

Agenda

Here is an overview of the academic calendar for the quarter ahead and the themes and subjects of lectures and labs.

Week No.	36	37	38	39	40	41	42	43	44	45
Quarter	Quarter 1									
Teaching week	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*
Monday	31-Aug	07-Sep	14-Sep	21-Sep	28-Sep	05-Oct	12-Oct	19-Oct	26-Oct	02-Nov
Tuesday	01-Sep	08-Sep	15-Sep	22-Sep	29-Sep	06-Oct	13-Oct	20-Oct	27-Oct	03-Nov
Wednesday	02-Sep	09-Sep	16-Sep	23-Sep	30-Sep	07-Oct	14-Oct	21-Oct	28-Oct	04-Nov
Thursday	03-Sep	10-Sep	17-Sep	24-Sep	01-Oct	08-Oct	15-Oct	22-Oct	29-Oct	05-Nov
Friday	04-Sep	11-Sep	18-Sep	25-Sep	02-Oct	09-Oct	16-Oct	23-Oct	30-Oct	06-Nov
Saturday	05-Sep	12-Sep	19-Sep	26-Sep	03-Oct	10-Oct	17-Oct	24-Oct	31-Oct	07-Nov
Sunday	06-Sep	13-Sep	20-Sep	27-Sep	04-Oct	11-Oct	18-Oct	25-Oct	01-Nov	08-Nov
What you do in these weeks	Programming	Configuring	Shaping			Structuring		Documenting	Making	Final Evaluation
	A0	A1	A2			A3		Document	Present	Rest
	0 Pts	15 pts	25 pts			30 pts		10 pts	20 pts	100 pts
due dates	04-Sep	11-Sep			02-Oct		16-Oct	23-Oct	30-Oct	

Roster

The roster might slightly change due to possible late confirmations/cancelations from guest lecturers.

All lecture sessions will be held on Zoom, for which you shall receive an invitation link on Brightspace.

All consultation sessions will be held on Discord. You shall receive an invitation on Brightspace for joining this environment.

Week	Day	Date	To Do	AM1 (9:00-9:45)	AM2 (10:00-10:45)	AM3 (11:00-11:45)	AM4 (12:00-12:45)	Break	PM1 (14:00-14:45)	PM2 (15:00-15:45)	PM3 (16:00-16:45)	PM4 (17:00-17:45)
1	Tuesday	01-Sep	A0: warm up	Course Intro. and grouping, PZN		Configuring Earth & Masonry Architecture, Nour Abuzaid			Rudiments of Linear Algebra and Computer Graphics, PZN		Earth Arch., Ir. Juriaan van Stigt, LEVS Architecten	
	Thursday	03-Sep		Computer Geometry & Topology, PZN		Programming I: Introduction to Python, SAZ, HHG, PZN			Design Studio: Ideation (Configuring)			
2	Tuesday	08-Sep	A1: Configuring	Earthship Architecture, SSZ		Programming II: Python and Voxels, SAZ, HHG, PZN			Design Studio: Consultation (Configuring)			
	Thursday	10-Sep		Graphs & Fields, PZN		Programming III: Digital Brick-Laying, PZN,SAZ, HHG			Programming IV: Functions & Calculus, HHG, SAZ, PZN			
3	Tuesday	15-Sep	A2: Shaping	Material Science of Earth, FVR		Bricking Lecture and Workshop, Ir. Koen Mulder			Karamba Workshop, Ir.Shibo Ren, ARUP			
	Thursday	17-Sep		FEM for Earthy Buildings, FVR		Structural Design with Earth, DRZ			Design Studio: Consultation (Forming)			
4	Tuesday	22-Sep		Dynamic Relaxation, PZN		Programming V, NumPy and Dynamic Relaxation, SAZ & Kotryna Valeckaite			Design Studio: Consultation (Forming)			
	Thursday	24-Sep		FEM and Research, FVR		Graphical Equillibirium Analysis, Prof. Philippe Block, BRG			Programming VI: COMPAS, Dr. Tom van Mele, BRG			
5	Tuesday	29-Sep		Research, Design and Development					Design Studio: Consultation (Forming & Structuring)			
	Thursday	01-Oct							Midterm Review (Pinup Presentation)			
6	Tuesday	06-Oct	A3: Structuring						Design Studio: Consultation (Structuring and Forming)			
	Thursday	08-Oct							Design Studio: Consultation (Structuring)			
7	Tuesday	13-Oct							Design Studio: Consultation (Construction Design)			
	Thursday	15-Oct							Design Studio: Consultation (Structuring)			
8	Tuesday	20-Oct	Documenting						Design Studio: Consultation (Code Documentation)			
	Thursday	22-Oct							Design Studio: Consultation (Shareable Technical Reports)			
9	Tuesday	27-Oct	Making & Presenting									
	Thursday	29-Oct							Final Presentatios and Feedback			
10	Tuesday	03-Nov	Evaluation	final submission deadline								
	Thursday	05-Nov		grading by instructors								

Evaluation

The evaluation is based on assessing the quality of the deliverables (documented code, procedural models, a report, and a presentation) altogether is referred to as the 'presentation'. Your work will be judged both in terms of the quality of the models and their contribution to the design process. We deem documentation & presentation in the broadest sense as the means to explain and justify the use of the developed models. Proper referencing and citations of other people's works is mandatory. That is, you are expected to be able to explain how things work and why you are using the things you have found.

NOTE that this 15 ECTS course requires a [minimum] of 15x28=420 hours of your engagement. This means that students are required to spend at least **280 hours (unsupervised learning hours)** on learning and design (which includes working on assignments).

The following formula shows the marks corresponding to the assignments (A1, A2, and A3), the quality of documentations (D), and the final presentation (P). We reserve the right and respect the duty to differentiate individual grades in case of under or over performance in terms of teamwork on assignments. Be aware that we shall carry out two peer-evaluation procedures (mid-term and final) in order to verify our observations on individual performance in groups.

Every single team member can be held responsible for everything that the groups is doing and thus teachers can ask any question to any team-member, as long as the question pertains to one of the issues in the scope of the course.

0(A0)+15(A1)+25(A2)+30(A3)+10(D) +20(P)= 100 pts

The final examination corresponds to the final presentations (process & product) and it constitutes only 20% of the final grade. However, according to the regulations, in order to pass the final examination, one must get at least 55% of 100.

Rubric

The following rubric will determine the level of grades for every deliverable (to be applied as percentages). The grades will be first given out of a 100, averaged, and then rounded to the scale of 10 systematically, i.e. to the nearest multiple of 0.5.

Label	***Mark***	***Explanation***
Wretched	1-2	There is not enough evidence for assessing any meaningful contribution attributed to the individual in question.
Poor	3-4.5	Has done things sporadically but has not had a sufficiently meaningful contribution to the project.
Deficient	5-5.5	Has contributed to all deliverables but not done enough to reach a sound design, has not fully taken the complexity of the assignment into account, and thus the final results, as well as processes lack sophistication.
Sufficient	6-6.5	Has done everything necessary at a basic level to get to a sound design but the result as well as the process do not present any innovation. The complexity of the problem has been not been taken into account and the results are primitive or incomplete.
Fair	7-7.5	Has adequately utilized existing techniques to produce sound designs, however, the approach is still simplistic and does not fully take into account the complexity of the problem. There are a few useful methods developed in GH or in Python.
Good	8-8.5	Has gone at least a few small steps beyond existing techniques and attempted to achieve not only sound but also elegant designs. A few useful and noteworthy methods are developed and well documented in GH or in Python.
Excellent	9-10	Has gone quite a few steps beyond existing techniques, extended the presented knowledge, and achieved not only sound but also elegant designs. There are noteworthy technical contributions in GH or in Python.

Scope: The Text versus the Margin

What is the main subject and what are the marginal subjects? The Main Subject is Computational Form-Finding and Computational Construction Design. Computational means through Algorithms (implemented e.g. in Python=Esperanto of this course, and/or neat, reusable, and well-documented GH models). Therefore, the scope includes:

- *Space Planning*
- *Earth Architecture*
- *Construction Design*
- *Programming (Algorithms implanted as procedural GH models or in Python)*
- *Mathematics (Linear Algebra, Geometry, Topology, Graph Theory)*
- *Form-Finding (Shape Optimization)*
- *(Optional) Topology Optimization*
- *Structural Design (FEM, structural analysis, structural design principles for earthy or masonry design)*
- *Material Science (of earth construction, how to engineer non-standard materials and cope with low-tech construction)*

The flowing subjects are somewhat related to the course, nevertheless <u>they fall out of the scope of the course</u>. Here is why:

- *<u>Social Sciences?</u> Yes, definitely necessary in the planning phase, but we do not have enough time and expertise to dive deep enough into this dimension, thus they fall out of scope.*
- *<u>Sustainability, Circularity, or Resilience?</u> Yes, they are always in the background as principles, but we have a very specific, limited, and yet intensive technical scope which does not leave enough time to go into depth of any of these subjects.*
- *<u>Climatic Design?</u> Yes, relevant: guidelines and principles (as well as common sense) must be respected. Besides, earthy buildings are known to be climatically quite comfortable if constructed reasonably. However, there is absolutely no time for light simulations and alike. In that sense, climatic design or climatic analysis falls out of the scope of EARTHY.*
- *<u>Material Research?</u> Chemistry of Earth, recycling plastics, etc. is rather related to our subject but fall out of the scope.*
- *<u>Artificial Intelligence?</u> If meant as a branch of magic, irrelevant. If meant as nature-inspired computing, yes; but we do not think there is possibly enough time to dive into this subject deep enough to talk about it in a meaningful manner.*

<u>A Phenomenological Perspective on Procrastination:</u> "If you procrastinate, you keep leaving things you should do until later, often because you do not want to do them". (Collins Dictionary). We all know what procrastination is like, and we should admit that there are more advanced forms of procrastination: when you are prepared to study biology or 'wash the dishes' instead of doing the difficult task at hand (e.g. FEA). We do not afford to allow that. You are advised strongly against jumping into marginal subjects even if you have the best of intentions.

Assignments

Groups of students will work on assignments together. In case of group work, everyone contributes in everything including programming and prototyping (Physical/FEM/GH/Python/C#) and in writing the reports. Students can define and choose specialized roles in their group, on the condition that all roles relate to the learning objectives and the role is approved by all instructors. Note that no one can pass this course without doing a considerable amount of technical work (maths, programming, FEM analysis, etc.). The aim of this course is not to teach using software applications but to teach the fundamental mathematics and algorithms. Therefore, **students are expected to follow the software tutorials online in their self-study hours**. All results (codes, models, and wiki-documentation pages) produced for assignments must be submitted as open-source contributions to our repository on GitLab: https://gitlab.com/Pirouz-Nourian/Earthy. Lab/Assignment Tools: Rhino3D+Grasshopper3D or Houdini, Python, C#, Mathematics, pen and paper, hand tools, clay, etc.

Advices

This course is the result of convergence of interests and efforts of a group of dedicated professional people. We enjoy preparing it, teaching it and working alongside you on it to learn and develop it furthermore. Our vision is that accumulation of the efforts of lecturers and students will gradually produce a useful body of knowledge. However, our combined enthusiasm has made it an ambitious course with a very intensive schedule; you can read in the study hours that in 8 weeks you must work more than 60 hours per week. We are a big group of teachers and it is only natural that we might have different opinions about various matters. Commentary about workload and difference of opinions between teachers is thus not appreciated. You are responsible for designing and engineering a sound building and thus you yourself decide what to do for your own project, we only advise and teach generic subjects (the fundamentals of computational design, structural design, and material science) and provide support in developing your design methods and models as much as possible. However, there is no such thing as effortless learning. In the context of this course, you need to take extra steps to connect the subjects and concretizing the teachings of all teachers. Hard technical work is key to success in EARTHY. EARTHY is about working hard for learning a lot and making a difference. If you want to learn well, then naturally you might have to spend some extra time to remedy your knowledge in mathematics, computation, structural analysis, material science, etc. As much as we encourage constructive criticism and concrete suggestions for improvement, we discourage 'bargaining for doing less and getting a higher grade'. If you insist that you do not want to learn; then we will not insist.

The context in which we want to intervene is highly complicated, socially, politically and economically. As much as we care about it, we forbid ourselves to dive into the context surrounding the displaced community because we are no experts in any of these areas and we can only work on architectural engineering subjects in 8 weeks. We will show our care by proposing workable technical solutions, hoping they will be of some use, especially when properly documented and shared with the public. Lastly, we should like to remind you that we only discuss physical matters in the class, and that all metaphysical subjects fall out of scope of this course. We believe that an open and inclusive approach toward diversity not only creates a positive atmosphere for collaboration, but also helps us to benefit from this multitude of cultural perspectives by creating a prolific context for innovation. We encourage you to form groups of maximum diversity of nationalities, gender, skillsets, educational backgrounds, etc.

Regarding the rubric and the evaluation process, please bear in mind that the minimal sufficiency levels should not be considered as targets to reach but rather as legal text explaining what happens at the border of worst-case scenarios (failing).

Presentations

For your mid-term and final presentations, please prepare a concise and to-the-point presentation for the mid-term directly aimed at explaining your products, processes, and the reasoning behind them. Due to the limited time frame, it is recommended that you aim for a presentation of a maximum of 25 minutes, ensuring that you have explained your best results and conclusions in the first 5 minutes. Instead of spending your time extensively talking about the problems of the site, that we are all aware of, use that time to talk about your 'formulated design problems' and your 'proposed design solutions'. A design problem starts with an objective to do something in a certain way, it is not a societal problem, it is rather a mathematical/computational problem related to planning (pertaining to matrices/graphs), configuring (pertaining to layouts/topologies), forming (pertaining to shapes/geometries), or structuring (pertaining to stability and constructability of forms). Therefore, formulate your design problems in the form of 'how-to' questions expressing an objective with respect to such objects of interest. Presentations are timed as below:

14:00-14:30	14:30-14:45	14:45-15:15	15:15-15:30	15:30-16:00	16:00-16:15	16:15-16:45	16:45-17:00	17:00-17:30	17:30-17:45
1	Q&A	2	Q&A	3	Q&A	4	Q&A	5	Q&A

Assignment 0: Preparations

To prepare for the first workshop you need to know the interface and basics of Rhinoceros and Grasshopper, as well as the basic Python node (GH Python). In parallel to these software preparations, however, you need to work together as one whole class on the master planning of the site. See below instructions for these two assignments:

Title	*A) Software Installations*
Objective	To get all the necessary tools up and running and familiarize yourself with the UIs
Notes	If you need a Windows OS on your Mac; for further info and support on how to do this please go to @hoc: http://adhok.bk.tudelft.nl/site/info/windows-on-mac/
Description	*Required Installations for the first Practicum (at home)* Needed software packages: Rhino 6 and Grasshopper **Rhinoceros 6.0**: Can be downloaded from software.tudelft.nl, Go on Installation tab and follow the instructions. **Grasshopper**: from http://www.grasshopper3d.com/ **Anaconda (optional environment for learning Python)**: Anaconda is to be installed for Python 3.X (also available through software.tudelft.nl) **COMPAS (optional library for working in Python):** using Anaconda is recommended, starting up **Houdini (optional geeky alternative to Rhino & GH):** https://www.sidefx.com/download/ • *[Optional] If planning to write everything in Python then install GH-CPython (for using SciPy & NumPy) Configure your CPython node to use the Python 3.X of your Anaconda to run. You need to locate the Python installation of your Anaconda for this purpose: [Open the Anaconda Prompt and type: > where python]* • *[Optional] If planning to write in C#: install Accord.NET* • *[Optional code editor] Visual Studio Code could also be installed from the 'Anaconda Navigator'.* [Optional] Ansys, COMSOL, or an open source alternative such as Calculix for FEA of structures are both available through software.tudelft.nl
Platform	*Getting started with Rhino and Grasshopper:* Rhino tutorials: http://www.rhino3d.com/tutorials http://vimeo.com/58212839 (must watch & practice, about 5 minutes) http://vimeo.com/82431575 (must watch & practice, about 1 hour) https://vimeo.com/28175502 (must watch & practice, about 2 hours)
Plugins	The following tools might be useful for your project: Kangaroo, Weaverbird, RhinoVault, Karamba3D, Mesh+, SYNTACTIC, SpiderWeb, & **Rasterworks.dll** (Voxel and Iso-surface Tools: 1, 2, 3, 4)
Title	*B) Configuring: master planning for the neighbourhood and the key building types*
Objective	To propose a master plan for the future de-facto development of the camp into a small town
Procedure	**Analysis**: Analyse the site in terms of intensities of population, activities, highlighting the infrastructure and seeking to reveal the invisible connections as well as flows of people and goods between points of interest. **Synthesis**: Interpret the analyses and put them together to form a conclusion regarding how things work right now. **Evaluation**: Identify the missing buildings and the connections that need to be strengthened or improved. **Proposition:** Propose a list of communal buildings or mega buildings (such as bazars) to be designed and then envision and list stages of spatial improvements that can be feasibly realized by the community.
Deliverable	• *A master plan highlighting the main infrastructure veins to be improved articulating slow traffic routes as well as vehicular traffic routes, highlighting the missing connections to be added.* • *A zonal plan indicating what needs to be added in each zone* • *This assignment is done by the entire class as a whole. It is not graded. However, reported or observed underperformance of individuals will definitely result in a negative grade.*

Assignment 1: Configuring

Title	Configuring: space planning for the neighbourhood and the key building types (10 pts)
Objective	Formulate the design problems, goals, the idea, and a matching conceptual configuration
Inputs	The inputs are publicly available data about the site, especially the UNHCR documents.
Procedure	Describe the hierarchy of design decisions, formulate design goals, define design principles, and identify stages in the design process that could be supported by algorithms. Compose a Programme of Requirements (PoR) containing a list of functional spaces (open, semi-closed, or closed spaces), their desired areas, minimum free-heights, and preferred orientations as to daylight requirements. Indicate the desired spatial connections between the proposed spaces in a REL Chart. Draw a bubble diagram of the PoR.
Deliverable	Process-Related Deliverables: • *The Main Design Problems minimum 3 and maximum 5 design problems, each of which to be described in maximum 20 words.* • *A Flowchart as dynamic decision-making tool needs to be set-up. A good flow-chart is a good map of the process that is being explored and devised; does not contain too much details; it is not a one to one representation of the reality of the process, but the big picture. As a general guideline, it is not recommended to have not more or less than 5 to 10 process components in the first version of the flowchart.* Design-Related Deliverables: • *A Programme of Requirements* • *A REL-Chart* • *A Bubble Diagram* • *A MarkDown page on your git repository, containing 100 words and images/tables of the above*
Quality Levels	In general, sound and complete deliverables will get a sufficient mark. The quality of the design-related deliverables is assessed in terms of the eloquence of their presentation as well as the justifications and explanations that relate these products to the goals, design principles, and the idiosyncrasies of the context. A sufficient flowchart is a complete picture of the process with the nature of inputs, outputs, and processes specified consistently. A configuration is sufficient if it fulfils all the functional requirements, and it is excellent if it clearly explains the "added value" of the building as to the inter-relations of the functional units within the building and its integration within the context. Excellence is also assessed as to the degree to which the reasoning is objective and documented.

Assignment 2: Shaping

Title	Shaping: architectural design of the key building types (30 pts)
Objective	Develop (computational) methods and strategies to generate a shape from a spatial configuration
Inputs	From the deliverables of the previous assignment: the REL-Chart and/or the Bubble Diagram
Procedure	Design a grid-based schematic layout of the building, based on the REL-Chart/Bubble-Diagram. Map, transform, or adapt the schematic layout onto your site procedurally, e.g. by [Grid-Snapped] Manual Mesh Modelling, converting nodes to boxes, and Boolean union of boxes; or by designing a 3D Carcassonne, i.e. making your own Carcassonne pieces and their graph grammar and replicate your graph with these pieces. Describe how you have methodically/procedurally converted design ideas and concepts the computer geometry of the building.
Deliverable	• *A low-polygon mesh delineating the basic shape of your building with the tessellation of the roofs explicitly designed topologically. All spaces whether open, semi-closed, or closed must be properly tessellated according to the mesh validity criteria mentioned in the lectures, and all spaces must be shaped and/or confined by the mesh model.* • *A MarkDown page on your git repository, containing 200 words and at least three images, pseudocodes, and a flowchart*
Quality Levels	The difference between sufficient and excellent is the extent to which it is done manually or computationally. Moreover, the quality of the shape is assessed in terms of the clarity and the due sophistication of its mesh topology. In any case, the validity of the mesh based on Euler-Poincare Characteristic is essential for a pass.

Assignment 3: Structuring

Title	Structuring: structural design and construction design of the key building types (30 pts)
Objective	Develop (computational) methods for form-finding, structural validation, and construction design
Inputs	From the deliverables of the previous assignment: the low-polygon mesh model of the entire building In addition, the bricks made in the brick-making experiments are to be tested in a kitchen-lab.
Procedure	Describe how you get to an optimal/sound adobe structure to realize the shape.
Deliverable	• *An excerpt of the material properties test results, brick making results, lessons learnt, and conclusions drawn.* • *A form-finding procedure whose inputs are based on the tested bricks* • *An excerpt of the process developed for procedurally constructing a structural model of the building.* • *A FEM model of the building and its simulation results, interpreted as a validation report.* • *A proposed method for constructing the complex parts of the building (typically the roofs)* • *A MarkDown page on your git repository, containing 150 words and sufficient images, tables, pseudocodes, and flowcharts explaining the items above* All models have to be uploaded to the repository.
Quality Levels	A sound structure is that which is validated in terms of the admissibility of the loads with respect to the estimated material properties such as the Young's modulus, Poisson's ratio, etc. and the insurance that the structure is to be a compression-only load-bearing form/shape. The difference between a sufficient (a sound structure) and an excellent structure is the degree to which the work is procedural/computational.

Documentation

Title	Documentation (10 Points)
Objective	Document the process and products and provide explanations to ensure repeatability of all experiments.
Inputs	The outputs of all previous assignments
Procedure	Neatly structure the outputs and push them to our public git repository
Deliverable	a git directory and a well-structured MarkDown page
Quality Levels	The principles for assessing the quality of the documentation are: • *the degree to which the generated data is FAIR (Findable, Accessible, Interoperable, Reusable); and* • *the degree to which the proposed results are "reproducible" by following the documentation,* Reproducibility obviously entails the repeatability of the process: (A particular experimentally obtained value is said to be reproducible if there is a high degree of agreement between measurements or observations conducted on replicate specimens in different locations by different people—that is, if the experimental value is found to have a high precision. Both of these are key features of reproducibility. From: https://en.wikipedia.org/wiki/Reproducibility) A repository and a report structured according to the template given below with enough content pertaining to the project of the team can be regarded as sufficient if the contents are consistent and coherent and that they are sophisticated enough in accordance with the goals of the project. What distinguishes an excellent documentation from a sufficient one is the visual clarity and coherence for navigation into the content and a consistent set of visuals produced from a limited set of vantage points.

— Documentation Guideline——

Report

- *Chapters: {0_Introduction, 1_Configuring, 2_Shaping, 3_Structuring, 4_Reflection*

————————

Code

- *Including the **author name** and **date** at the beginning*
- *including a short description of the code*
  - *including an overview of the structure in terms of {classes, functions, etc}*
- *inline comments for lines that their purpose may be ambiguous*
- *if you are using a node-based software (eg Houdini, grasshopper, etc):*
  - *include the main file (*.hipnc, *.gha, etc)*
  - *group nodes/components that are aimed to perform a task together and name them accordingly.*
  - *Use **Null Node** in Houdini and **Data Components** in Grasshopper as inputs and outputs of each group.*
  - *save a pdf of the network*
  - *includes notes to describe the inputs and outputs*
  - *save the code snippets separately as well*
    - *if there are complementary files: { their path need to be **relative &** They need to be included}*
- *if there is more than one file that is supposed to work together in a bigger workflow, it is necessary to include a flowchart explaining the relation of different files and the data model of the files transferred between them*

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Visuals

- *Camera*
  - *save camera angles and export all your analytical visualisations/diagrams from the same angle.*
  - *If it is necessary, try to limit the number of cameras.*
  - *If you are using an orthogonal projection (either 2D or 3D) include a scale*
- *Colours*
  - ***Always** include a legend for the colours and explicitly mention what they are representing (quantitative or qualitative)*
  - *Be consistent with the usage of colours through your project*
- *Style*
  - *visualisations must not be superficially decorated but instead present a coherent and consistent set of visuals.*
  - *Your visualizations are not assessed in terms of their beauty but their information content and clarity.*
  - *visualisations are made to facilitate representation of your project, therefore it is important to keep them clear and consistent.*

————————

Presentation

<table>
<tr><td>Title</td><td colspan="2">Presentation of Processes and Products (20 pts, considered as the final exam)</td></tr>
<tr><td>Objective</td><td colspan="2">Present (explain and justify) the structured collection of design methods (design methodology) and results

Note: the final presentation will be also considered for revising the grades of the previous assignments, therefore do your best!</td></tr>
<tr><td>Inputs</td><td colspan="2">The outputs of all previous assignments</td></tr>
<tr><td rowspan="3">Deliverables & Procedures</td><td>**Slides**</td><td>• *A perfectly structured presentation of 15 minutes: that is structured according to a flowchart describing your design process and showing a sufficient number of images. The presentation should give adequate and specific information on your design to an outsider. Focus on the configuration, the shape, the structure, and the proposed construction process. Every team member is given an equal time to speak during in the presentation. Your oral presentation is important but higher weight is given to the quality of your slides and the extent to which they are consistent and coherent.*</td></tr>
<tr><td>**Poster**</td><td>• *A professionally designed A2 poster: that is a self-contained poster as a competition entry, containing artistic impressions bird-eye views, outside views (human eye level) and inside views of the building, a plan, at least 2 vertical sections, structural model and validation results, brick making and material analysis results, a visual explanation of the proposed construction technique. A concise explanation of 150 words must be included in the poster. The names of the contributors and studio information must appear on the poster as well.*</td></tr>
<tr><td>**Physical Models**</td><td>• *A perfectly made physical model: that is a solid, sturdy maquette at the scale of 1:50/1:100 of your building containing bricks, screws, bolts, nuts, and/or rivets. You are NOT supposed to 3D print the whole thing at once. You are supposed to make it from pieces as a puzzle. Make sometime you could be proud of!*
• *Make a construction mock-up prototype of 1:20/1:50 presenting the gist of your construction process.*</td></tr>
<tr><td>Quality Levels</td><td colspan="2">The specific quality aspects are mentioned above with respect to each deliverable. In general, the excellence of the presentation is assessed in terms of the clarity and the rationality of your explanations and your reasoning behind your design decisions.</td></tr>
</table>

— Presentation Guideline——

- *the aspect ratio of slides must be 9:16*
- *number the pages*
- *structure your presentation into chapters and highlight which chapter we are at in each slide (preferably use your flowchart as the main map of your presentation)*

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Folder Structure

- *Group [group number] - [project title]*
  - *A1_Configuring*
    - *Process: {Code, Flowchart, Game}*
    - *Product: {Model, Animation, Scenarios, Diagrams, Visualisations}*
  - *A2_Shaping*
    - *Process: {Code, Flowchart, Tessellation}*
    - *Product: {Model, Animation, Diagrams, Visualizations}*
  - *A3_Structuring*
    - *Process: {Code, Flowchart}*
    - *Product: {Model, Animation, Diagrams, Visualizations}*
  - *Final Deliverables*
    - *Final Presentation*
    - *Final Report*
    - *Final Physical Models [and their pictures]*
    - *Final Poster*

Literature

In this course, we teach the basics of computational design, structural design and material science necessary for design and engineering earthy building. These references are for further methodological reading, technological know-how (e.g. related to software) can be strengthened by preparation for and active participation in workshops*.

***Methodology:** Mathematical Formalisms, Computational Methods (Algorithms represented as pseudo-code) and Data Models

***Technology:** Programming Languages, Standards, File Types, Software Applications, IDEs, Robotics, Power Tools, etc.

Computational Design Literature:

The course involves quite some mathematics and computation. You are advised to remedy your math knowledge by reading extra books e.g. [1] pp.137-181 [2] pp.29-51, [3], [4] pp. 9-26 & pp. 225-236. Most of the topics about computer geometry are covered in [5] pp. 1-5, 7-13, 21-24, 29-33 and [6] pp. 62-63. Highlighted pages are the least you are recommended to read from the following books. For computational/combinatorial design look at [7], [8], [9]. For getting started with programming, check [10] [11].

Earthy Architecture:

Start with [12], [13] and [14], continue then with [15], have a look at [16] and [17], and try to find [18].

Structural Design:

Read [19], also read [20], then continue with [21], [22], [23], [24] and check [25] for Earthquake resistant earthy building.

Material Science:

Read the followings: [26], [27], [28], [29], [30], [31], [32], [33],

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Miscellaneous Nuggets

A BSc Thesis on Earth Architecture

A Presentation on Mud Construction

Interlocking Earth Blocks by UN Habitat

Hassan Fathi Presenting the Nubian Vaulting Technique

Building with Earth, pp. 117-126, introducing a 3D version of the Nubian Vault technique referred to as the Afghan/Persian dome

Schedule of Afternoon Consultations

With the limitation that COVID-19 has projected to the education sectors, our course will be held fully online. We understand that consultations need flexibility in their duration, yet the online medium of consultation makes it harder to have consultation session on first-come first-served basis. Here, we provide a detailed schedule of the Consultations for all the groups and all the tutors. We have tried to include at least two consultation sessions for each group on each day as well as an hour of Q&A for each tutor on each day. Students can be absent in 'no more than two sessions of consultations' regardless of the reasons.

Design Studio Consultants: 08 - Sep	14:00-14:30	14:30-14:45	14:45-15:15	15:15-15:30	15:30-16:00	16:00-16:15	16:15-16:45	16:45-17:00	17:00-17:30	17:30-17:45
Design Informatics (PZN)	1		2		3		4		5	
Design Informatics (HHG)	2		3		4		5		1	
Design Informatics (SAZ)	3		4		5		1		2	

Design Studio Consultants: 17 - Sep	14:00-14:30	14:30-14:45	14:45-15:15	15:15-15:30	15:30-16:00	16:00-16:15	16:15-16:45	16:45-17:00	17:00-17:30	17:30-17:45
Design Informatics (SAZ)	1		2		3		4		5	
Design Informatics (PZN)	2		3		4		5		1	
Design Informatics (HHG)	3		4		5		1		2	

Design Studio Consultants: 22 - Sep	14:00-14:30	14:30-14:45	14:45-15:15	15:15-15:30	15:30-16:00	16:00-16:15	16:15-16:45	16:45-17:00	17:00-17:30	17:30-17:45
Design Informatics (HHG)	1		2		3		4		5	
Design Informatics (SAZ)	2		3		4		5		1	
Design Informatics (PZN)	3		4		5		1		2	

Design Studio Consultants: 29 - Sep	14:00-14:30	14:30-14:45	14:45-15:15	15:15-15:30	15:30-16:00	16:00-16:15	16:15-16:45	16:45-17:00	17:00-17:30	17:30-17:45
Design Informatics (PZN)	1		2		3		4		5	
Design Informatics (HHG)	2		3		4		5		1	
Design Informatics (SAZ)	3		4		5		1		2	
Structural Design (DRZ)	4		5		1		2		3	
Construction Design (FSN)	5		1		2		3		4	

Design Studio Consultants: 06 - Oct	14:00-14:30	14:30-14:45	14:45-15:15	15:15-15:30	15:30-16:00	16:00-16:15	16:15-16:45	16:45-17:00	17:00-17:30	17:30-17:45
Design Informatics (HHG)	1		2		3		4		5	
Design Informatics (SAZ)	2		3		4		5		1	
Design Informatics (PZN)	3		4		5		1		2	
Construction Design (FSN)	4		5		1		2		3	
Structural Design (DRZ)	5		1		2		3		4	

Design Studio Consultants: 08 - Oct	14:00-14:30	14:30-14:45	14:45-15:15	15:15-15:30	15:30-16:00	16:00-16:15	16:15-16:45	16:45-17:00	17:00-17:30	17:30-17:45
Design Informatics (SAZ)	1		2		3		4		5	
Design Informatics (PZN)	2		3		4		5		1	
Design Informatics (HHG)	3		4		5		1		2	
Structural Design (DRZ)	4		5		1		2		3	
Construction Design (FSN)	5		1		2		3		4	

Design Studio Consultants: 13 - Oct	14:00-14:30	14:30-14:45	14:45-15:15	15:15-15:30	15:30-16:00	16:00-16:15	16:15-16:45	16:45-17:00	17:00-17:30	17:30-17:45
Design Informatics (PZN)	1		2		3		4		5	
Design Informatics (HHG)	2		3		4		5		1	
Design Informatics (SAZ)	3		4		5		1		2	
Construction Design (FSN)	4		5		1		2		3	
Structural Design (DRZ)	5		1		2		3		4	

Design Studio Consultants: 15 - Oct	14:00-14:30	14:30-14:45	14:45-15:15	15:15-15:30	15:30-16:00	16:00-16:15	16:15-16:45	16:45-17:00	17:00-17:30	17:30-17:45
Design Informatics (HHG)	1		2		3		4		5	
Design Informatics (SAZ)	2		3		4		5		1	
Design Informatics (PZN)	3		4		5		1		2	
Structural Design (DRZ)	4		5		1		2		3	
Construction Design (FSN)	5		1		2		3		4	

Design Studio Consultants: 20 - Oct	14:00-14:30	14:30-14:45	14:45-15:15	15:15-15:30	15:30-16:00	16:00-16:15	16:15-16:45	16:45-17:00	17:00-17:30	17:30-17:45
Design Informatics (SAZ)	1		2		3		4		5	
Design Informatics (PZN)	2		3		4		5		1	
Design Informatics (HHG)	3		4		5		1		2	
Construction Design (FSN)	4		5		1		2		3	
Structural Design (DRZ)	5		1		2		3		4	

Design Studio Consultants: 22 - Oct	14:00-14:30	14:30-14:45	14:45-15:15	15:15-15:30	15:30-16:00	16:00-16:15	16:15-16:45	16:45-17:00	17:00-17:30	17:30-17:45
Design Informatics (PZN)	1		2		3		4		5	
Design Informatics (HHG)	2		3		4		5		1	
Design Informatics (SAZ)	3		4		5		1		2	
Structural Design (DRZ)	4		5		1		2		3	
Construction Design (FSN)	5		1		2		3		4	

Design Informatics	Design Informatics	Design Informatics	Structural Design & Mechanics	Design of Construction
Pirouz Nourian	Hans Hoogenboom	Shervin Azadi	Dirk Rinze Visser	Frank Schnatter
PZN_Room	HHG_Room	SAZ_Room	DRZ_Room	FSN_Room

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Colophon

Published on GitLab: https://gitlab.com/Pirouz-Nourian/Earthy

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