

## **EARTHY: Generative Design for Earth and Masonry Architecture**

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# EARTHY:

## Computational Generative Design for Earth and Masonry Architecture

This is the author version of [an article published in the bulletin RUMOER, issue 74, pp. 47-53](#)

Pirouz Nourian, Shervin Azadi, Hans Hoogenboom, Sevil Sariyildiz

### 1. Etymology

We chose the name EARTHY for this course mainly to emphasize the focus on earthen and masonry-only architecture. However, the literal meanings and the connotations of the word [Earthy](#) were ironically all relevant as well: worldly as opposed to ethereal or Martian, natural, inartificial, unpretentious, down to earth, practical, pragmatic, and direct. Aesthetically, EARTHY is a quest for designing a [Khaki Paradise](#) for those who have suffered from disasters.



*Figure 1: student work sample from Earthy 2019, project Modulabitat, a social housing complex, image credits: Alessandro Passoni, Alessio Vigorito, Kiana Mousavi, Fredy Fortich Mora, Stephanie Moumdjian. Earthy buildings can provide shelter as well as an affordable level of elegance, identity, and a sense of community.*

### 2. Introduction

[EARTHY](#) is a master's level design studio offered by the [chair of Design Informatics](#) in collaboration with the [chair of Structural Design and Mechanics](#). As the name suggests, the course is about 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, forms, and structures, explored computationally. Automated construction design and generation of assembly instructions are extra challenges to be tackled via computation.

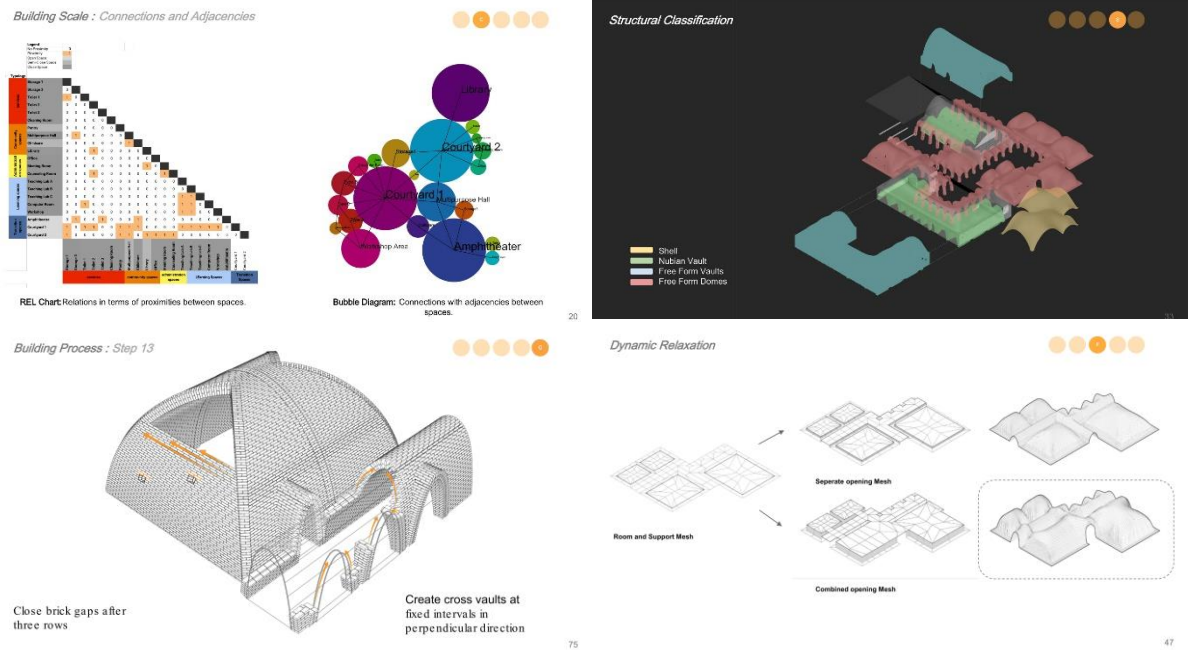


Figure 2: student work sample from Earthy 2019, project Adobe CCC, a skill development center, image credits Tarang Gupta, Divyae Mittal, Prateek Wahi, Andrea Fumagalli, Filip Zieliński, and Aditya Parulekar. Stages of the design process can be seen as configuring, shaping, structuring, and construction design.

### 3. Design Challenge

The task is to design for the betterment of [a district of] the [Al Zaatari Refugee Camp in Jordan](#). The course is prepared for a maximum of 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 eight 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.

## 4. Motivation

Earth architecture is a sustainable choice, especially in arid climates, because of using mostly in situ available materials, thus removing the need for carbon-intensive transportation, low/zero-carbon energy content of building materials, the excellent climatic performance of earth buildings using passive design strategies, etc. In addition, building only with earth/masonry materials provides an ideal didactic context for learning computational design as it presents the structural design and constructability challenges that can be dealt with through computational design, where the optimality of the shape is critically important for the stability of the structure. Earthy buildings need to be mostly compression-only structures, and that entails that they end up having complex geometric shapes. Earthy structures typically require vernacular building technical crafts, which are scarce in the designated site. Hence, novel engineering methods are needed to make such complex-shaped buildings easily constructible.

### 4.1. Mathematics

Typically, within architecture curricula there are bits and pieces of mathematics in a few courses related to the physical aspects of architecture but no course with a focus on how to derive configuration, shape, and structure mathematically or computationally. We initiated Earthy with a strong sense of mission and passion for emphasizing on a coherent structure for engineering mathematics and computation to building technology students before they graduate. By introducing computational models, Earthy aims to bypass the cliché of “dull maths” and demonstrate the myriad of its potential, and the usefulness of the mathematical formulation of design and construction problems. Moreover, the course exploits the close spatial relations of configuration and structure in earthy buildings in order to suggest a coherent mathematical/computational framework for computational design.

### 4.2. Computer Science

The same can be said about essential computer science knowledge (algorithms and data structures) and skills (programming). The other reason behind setting up this course was to play a proactive role in fulfilling the ‘technology research and development’ mission of the chair of Design Informatics and the Department of Architectural Engineering & Technology. The cutting edge of scientific and engineering fields is being pushed forward with a combined force of mathematics and computer science. It must be noted that there are no shortcuts in science and technology; and that breakthrough are earned by hard and reflective work. It may be possible to ‘use’ or ‘consume’ the most advanced technological tools without profoundly understanding their fundamentals, e.g., as in using a laptop without knowing anything about computer science. However, when it comes to technology development or technology innovation, one cannot get far from mediocrity without rigorous mathematical knowledge and computer programming skills. It is interesting to observe that in an innovation-driven organization such as NASA, not so long ago, even the so-called ‘secretaries’ used to be computer programmers<sup>1</sup>. Our vision for setting up earthy, from a skill development perspective, was to empower students by teaching the underlying fundamental mathematical/computational concepts of computer-aided design (a.k.a. computational and generative design) and enable them to partake in its development, ideally going beyond fiddling and tinkering towards rationalizing and composing. Specifically, Earthy covers the fundamentals of computer science (algorithms and data structures), as well as the rudiments of mathematics for computational design, especially discrete mathematics and [linear] algebra.

### 4.3. Humanitarian Architecture

From a societal perspective, Earthy was made out of an interplay of realistic pessimism, pragmatism, and romantic optimism. The pessimist part was because of a sense of the pointlessness of the art and the science of architecture in the face of human losses and tragedies happening in the Middle East. The

pragmatist idea behind the course was to support the inhabitants to design and make a virtually cost-less settlement with what they can find under their feet, a 'technically impermanent' settlement and yet much more stable and humane than tents or steel containers<sup>11</sup>. The optimist thought was based on the very humanitarian foundation of the field of architecture as an artistic/scientific practice. We argue that architecture can not only provide shelters, but also accommodate culture, promote aesthetics and thus a sense of elevation and hope of deliverance from pain and insignificance, and eventually foster a balanced level of social integration and privacy at a larger scale. In our definition of the field, we colloquially also include the art of designing [urban/rural] human settlements in architecture. The romantic vision, even if far from the bitter reality, is as real and vivid as the pragmatism behind the design task of Earthy, and as such, it has seemingly resonated well with the majority of students in the past two years.

After all, we believe that this is our battle as architects to proclaim our relevance and earn intellectual esteem by focusing a little more deeply on the severe problems of the poor rather than only working for the rich. The consumerist propaganda maintains that the poor are poor because 'they do not work hard enough' and that the rich are rich because they are 'successful entrepreneurs'. There are many counterexamples to such insulting jabber and babble, but the most obvious are the people impoverished because of human-made or natural disasters, such as wars, earthquakes, floods, and alike. Once stricken with such disasters, in the post-apocalyptic scene, one often loses all symbols and carriers of wealth, status, and even identity. Honestly, we do not think that earth architecture is only for the poor, but for reasons to be explained further, we chose to focus on the betterment of the conditions of such distressed groups employing earth architecture. While we were in the process of setting up the course, someone told us that we would be accused of being hypocrite architects, those who live in ivory towers themselves but promote earth architecture for the poor. Well, that was a harsh and bitter point, but it triggered another idea about the course, focusing on human groups for whom earth architecture can be a genuinely pragmatic reviving solution. Even though there are also many examples of luxury homes and buildings built only with soil, the social image of earth architecture, even in countries with a rich cultural heritage of earth architecture, remains colloquially known as 'architecture for the poor'. Well, we can certainly take this as a source of pride rather than a stigma. Moreover, for displaced communities who are forced to live indeterminately within tents or shipping containers in a harsh cold/hot desert climate, an earthly paradise that they can build by themselves could be much more real, achievable, confidence building, and sustainable than a supposedly heavenly utopia that can only be made with lots of money and imported corporate-owned technology.

#### 4.4. Participatory Design

It would be appalling and shameful to take advantage of the distress some people go through to gain any kind of wealth or fame. In fact, we were not even comfortable writing these words to be published. However, after a long intellectual reflection, we decided to explain what was always 'between the lines' of our published course materials. Thus, we have so far kept a low profile and advised the students to downplay all kinds of promotional publicity regarding 'doing the right thing' for such communities in exchange for a focus on providing for 'doing things right'. Frankly, as much as we believe architecture can potentially play a positive role, we cannot delude ourselves into thinking that architecture can solve much of the social or economic problems, especially in the case of war-torn societies. Arguably, however, architecture can play at least three significant roles in this transitional period, namely in realizing decent shelters and accommodation for people; supporting the process of reconnecting parts of a fragmented society in a reflective and participatory manner; and providing a real context for learning technical and artistic skills in a meaningful connection to a regional cultural heritage. Our ideal form of design for such settlements is a process in which the inhabitants can design their buildings for

themselves, where we as architects are working as orchestrators and facilitators instead of playing the role of 'do-gooders' and prophetic visionaries. Due to the short time-frame of the course, however, we only afford to spend one week on this aspect literally; nevertheless, the idea of gamifying the process and flexibility with regards to the eventual inputs and requirements of the prospective inhabitants is well appreciated and respected by all students and teachers.

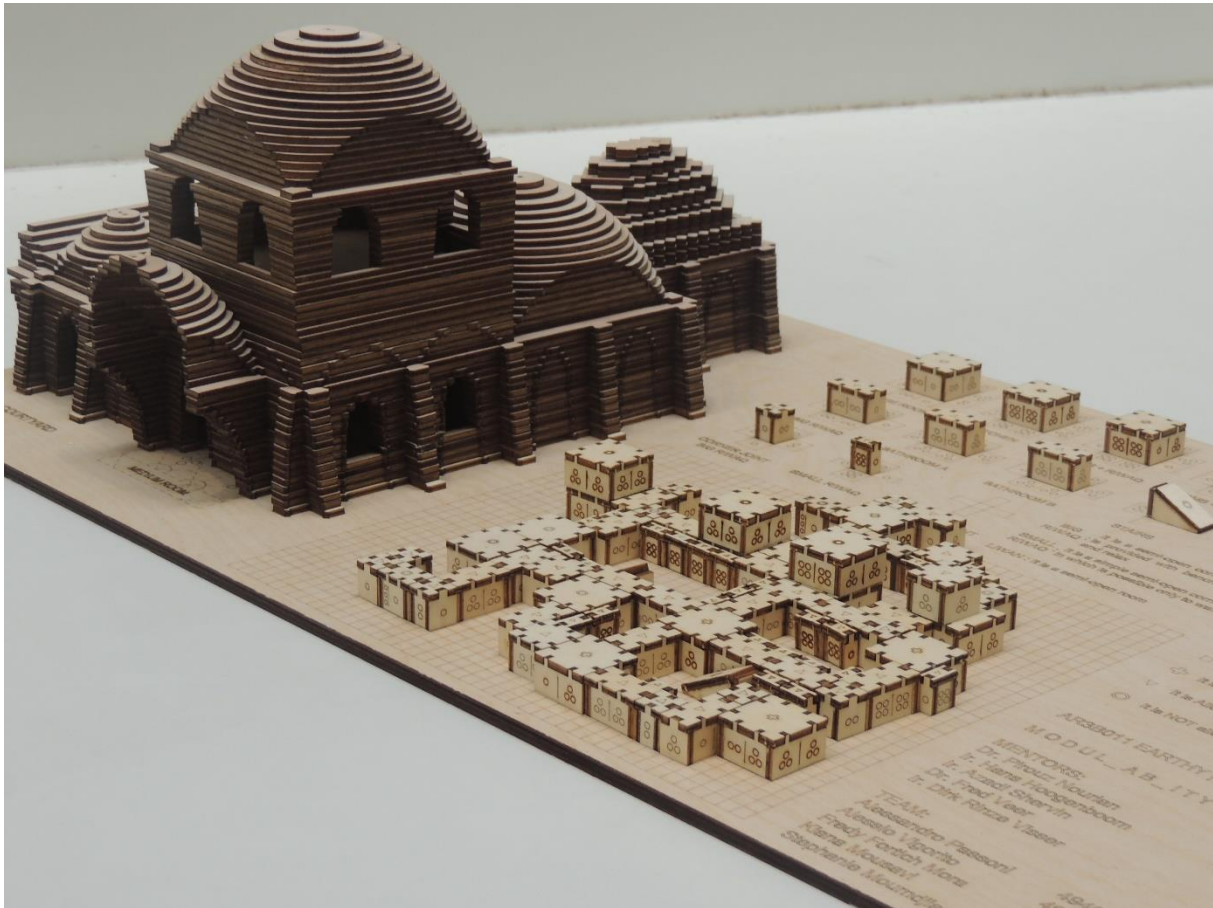


Figure 3: student work sample from Earthy 2019, project Modulabitat, a social housing complex, image credits: Alessandro Passoni, Alessio Vigorito, Kiana Mousavi, Fredy Fortich Mora, Stephanie Moundjian. The buildings can be designed by means of a participatory game developed by the team.

#### 4.5. Scientific Design

Philosophically, the school of thought behind EARTHY is to unite the art of building, civil engineering and architecture as they used to be, roughly speaking, before the 19<sup>th</sup> century (as Sigfried Giedion has articulated in his book *Space, Time, and Architecture* [1]) and prior to the proliferation of the [Beaux-Arts'](#) way of defining architectural education. By unification of architecture and civil engineering, we mean the inclusion of social, aesthetic, spatial, and structural functionalities of buildings into the design decision-making processes. In the words of [Vitruvius](#), we regard all three concepts of '*Firmitas, Utilitas, and Venustas*' as functionality. In the same light, we regard scientific design as a process directed by methodical deduction and discovery based on a comprehensive understanding of functionality. We promote this idea because not only it succinctly proclaims our direction in reuniting arts and sciences in design and architecture-craft, but also it implicitly centralizes nature, and the study of nature (physics, in its exact mathematical form), as the primary source of inspiration for design. Moreover, we in this context we interpret *venustas* into such qualities as purity of form, mathematical elegance, smooth transitions, balance, and equilibrium. At the same time, the so-called 'Arts and Crafts movement'

spearheaded by figures such as [William Morris](#) and [John Ruskin](#), as well as their esteem for cultural heritage, are as central to the spirit of the course as the [Bauhaus Movement](#) and its emphasis on combining functionality and aesthetics while bringing them into the logic of mass-production. Furthermore, the didactic philosophy of the Bauhaus Movement in concretizing the idea of unification of art, craft, and technology remains a source of inspiration for the course. Furthermore, the purist ideas of [de Stijl](#) movement and the rational, modular, and participatory initiatives of [Structuralism](#), especially those expressed by [N. John Habraken](#), are advocated in this course, although not taken literally or stylistically but rather from a process point of view.

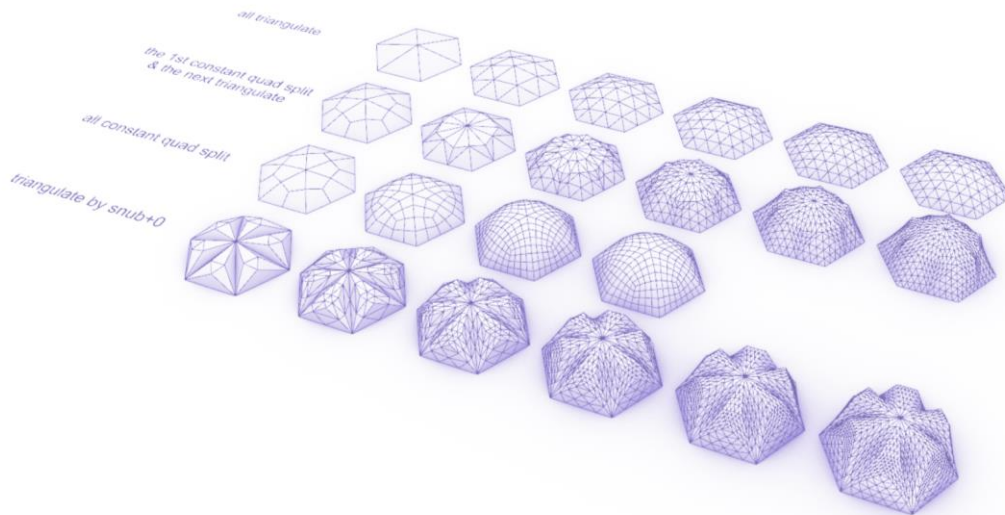


Figure 4: student work sample from Earthy 2019, project Hammam, a social housing complex, image credits: Hamid Reza Shahriari, Max Mandat, Hans Gamerschlag, Nikoleta Sidiropoulou, Noah van den Berg, Rick van Dijk. Generating and comparing various tessellation topologies with respect to their structural performance.

## 4.6. Architectural Heritage

More specifically reflecting on traditions in masonry architecture, the works of Catalan architects [Antoni Gaudi](#) & [Rafael Gustavino](#) provide recent precedents for masonry design in addition to hundreds of years of [Gothic Architecture](#), [Romanesque Architecture](#), [Armenian Architecture](#), [Byzantine Architecture](#), [Ottoman Architecture](#), [Moorish Architecture](#), and [Persian Architecture](#). Out of all schools of design in masonry architecture, Gothic Architecture and Persian Architecture are especial in terms of the purity of shapes regarding optimality, elegance, and reliance on compression-only materials<sup>iii</sup>. While almost all of these magnificent architectural traditions are regarded (or disregarded) as old architecture, it is ironically interesting to realize how little is known and taught in academia on their combined architectural and structural design methodologies. Apart from cliché academic pretensions, we must realize and admit that due to the historical detachment of architecture and civil engineering, much design knowledge and masonry expertise is lost in our fields. That said, however, the works of the [Block Research Group](#), especially the works of Prof. Dr. Phillippe Block on the modern and rigorous revival of the ‘Graphical Equilibrium Analysis’ (e.g., in [2]) are the most promising moves in reviving such lost knowledge. A significant part of this body of “[Techne](#)” has been historically focused on material-structure-form relations.

## 4.7. Material-Form-Structure Relations

The archetypical architecture associated with the so-called [MENA](#) region is one identified with arches, vaults, and domes; the archetypical European architecture ([Greek Architecture](#)) is associated with



triangular pediments; and that the roofs in traditional [Chinese Architecture](#) resemble tents, perhaps due to an old and rich tradition of nomadic cultures in vast steppes of central Asia. Are these associations all incidental? Most probably, they are not! It is evident that ‘building a roof over your head’ and ‘making a wide and glorious roof without so many columns, piers, and walls’ have been the most critical and persistent challenges of architecture as well as drivers of innovation and elegance in almost all traditional and vernacular architectural traditions<sup>IV</sup>, respectively for the commoners and the elite. An image must help make this point much clearer:

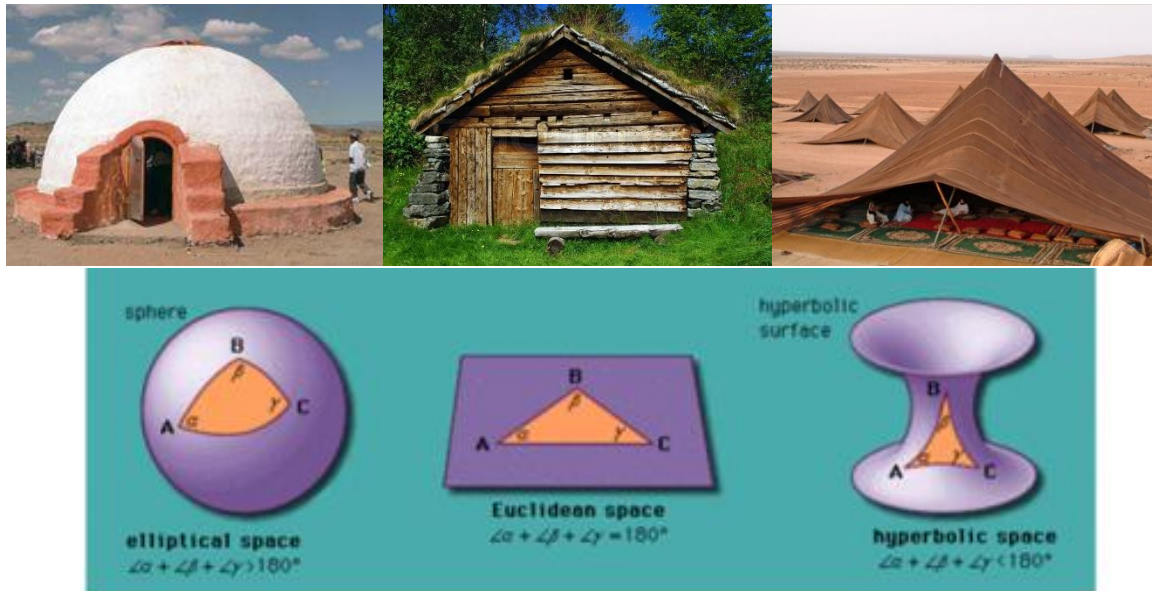


Figure 5: Archetypal Material-Form-Structure Relations, selection, collage, and emphasis by author, image credits: [Left](#)<sup>V</sup>, [Middle](#)<sup>VI</sup>, [Right](#)<sup>VII</sup>, and [Bottom](#)<sup>VIII</sup>

As evident from this analogy, geometry, as in the geometry from primary school and high school (Euclidean Geometry), would not be sufficient for designing 100% earthy buildings. In a modern pursuit of design methods for earthen or masonry buildings, we will need discrete mathematics to ‘compute shapes’ or ‘optimize shapes’ based on given functional requirements. This is why we find this design challenge an ideal context for an applied introduction to mathematics and computer-science for design.

#### 4.8. Multi-Scalar Spatial Planning

As a side note on the concept of functionality in the sense of *utilitas* (that is unfortunately often neglected), it is notable that despite apparent formal differences, many types of rural, traditional, or vernacular architecture share the same principles in structuring human settlements, as well as varying degrees of introversion embodied in the provision of [courtyards](#)<sup>IX</sup>. Even though courtyards are commonly associated with Middle Eastern architecture, they are also notably present in traditional Chinese architecture, Ancient Greek houses, and Roman architecture. However, in harsher climates such as the central desert of the Iranian plateau, courtyards not only exist in the architecture of the houses and almost all other types of buildings, but they also form the shape of the city. A world heritage city such as [Yazd](#) (the largest existing earthen city) is entirely structured upon a fractal network of courtyards, to the degree that one would always seamlessly traverse through narrow alleys from inside a courtyard to another. Many stereotypical ideas have been magnified about such labyrinths. However, the fact is that these courtyards are forming a protective network against the harsh climate of the desert, encompassing and protecting people against sandstorms, cold winds, hot winds, sunrays, as well as keeping the moisture of inner gardens and the fresh cool air of desert nights inside. In a settlement such

as the Al Zaatari refugee camp, the main urban challenge is the undefined and shapeless open abyss in between the containers. This unstructured space is a problem, mainly because it is indefensible, in that it does not provide any sense of human neighborhood in its hasty design, tragically manifesting many of the problems mentioned by Jane Jacobs, such as lack of neighborhood structure, walkability, and eyes on the streets. Interestingly, none of such problems is observed in organically grown cities. Thus, it can be argued that the urban design process must be participatory and that fractal-scaled neighborhoods must be facilitated to grow in such settlements as has been proven by the test of time in many places. At the same time, it is an art to control such an 'organic segmentation process', which could result in segregation and formation of ghettos or gated communities.

Another challenge related to the relation between inside and outside is the abrupt transitions that are not only problematic in terms of privacy and safety but also climatically wrong. In vernacular and organic architectures, peristyles, loggias, colonnades, liwans, and iwans usually provide a smooth, shadowed, and roofed transition from outside to inside, and as such, they provide environmental protection as well as privacy or security filtration. In particular, given a suitable orientation, an *iwan* in a desert climate tends to be so comfortable that it can be used as a dining place, living room, or even sleeping room for almost nine months of a year, only by providing shade from the sun and the sky.

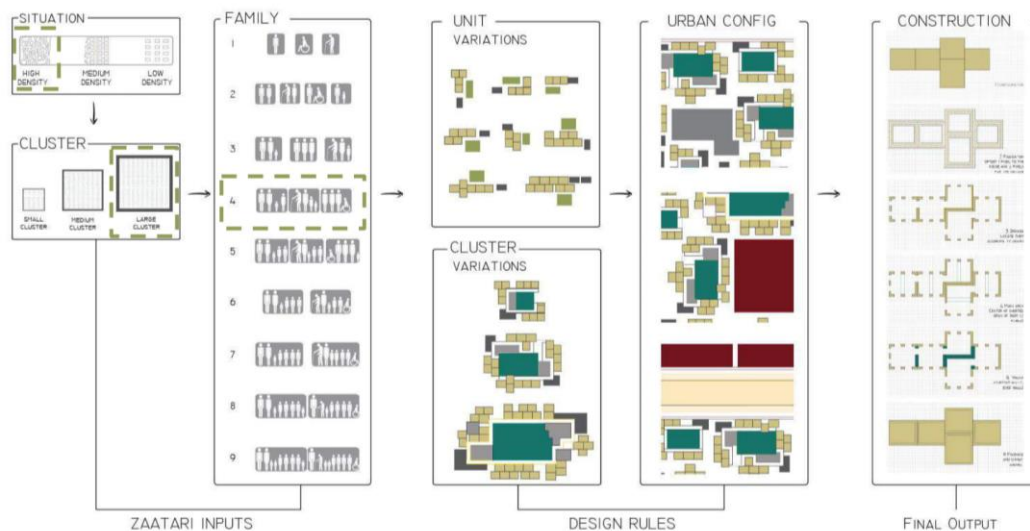


Figure 6: student work sample from Earthy 2019, project Bustan, a farm-housing complex; image credits: Akash Changlani, Shasan Chokshi, Kazi Fahriba Mustafa, Thai Wannasawang, Yara Z. Montemayor, Elisa Vintimilla Salas. The team proposed a game for participatory design of multi-scalar spatial configurations.

#### 4.9. High-Tech Design & Low-Tech Construction

At first sight, it seems that the complex relations of configuration and structure that articulate geometric forms for earthy buildings necessitate complex forms and the high-tech construction processes. However, by adopting a modular process-oriented approach to the design processes, we can contain the complex computations within the design process and simplify the construction process. In this way, the output of the design process is not merely the geometry of the building, but also a systematic low-tech construction process of that is closer to LEGO assembly than conventional construction. Such an approach entails that the design process needs to take into account the configuration of the space, the structure, the detailing of the elements, the materiality of the elements, and specification of the construction steps.

## 5. Approach: Generative Design for Earth and Masonry Architecture

Low-tech construction guided by high-tech design necessitates a shift of focus from the object to the processes of configuration. A mathematical translation of this shift can be formulated as a shift focus from geometry to topology. In other words, the focal point of attention in a topological approach to design is on the relations between the elements rather than those elements in isolation. This shift of focus, interestingly enough, also provides for making design processes accessible to a degree that they can be transformed into participatory games, thus enabling the inclusion of inter-subjective/social requirements into the design process. Furthermore, the same approach also provides a fundamentally systematic and digital way of ensuring optimality in fulfilling objective/physical design requirements. Generative Design is an umbrella term denoting processes for deducing spatial configurations based on required spatial functionalities, within a discrete space.

There are two dominant paradigms in computational design Creative Parametric Design and Generative Combinatorial Design. These two approaches almost directly correspond to the two dominant paradigms in design methodology, namely “Design as an Artistic Reflective Practice” [3], “Design as a Rational Problem-Solving Process” [4]. While there are many blurry cases and applications in which these approaches are both utilized in a single process, in order to clarify our definition of generative design, it is essential to distinguish them by highlighting their differences (see Table 1).

*Table 1: two dominant paradigms in computational design: Creative/Parametric Design vs. Generative/Combinatorial Design*

Procedural Design	
Computational Design	
Creative Design	Generative Design
Parametric Design	Combinatorial Design
Continuous Geometry Variations	Discrete Geometry Variations
Inherently Analog	Inherently Digital
Shape Optimization	Topology Optimization
Design as an Artistic Reflective Practice [3]	Design as a Rational Problem-Solving Process [4]

Given that our aim to develop low-tech constructible buildings, we refrain from designing shapes that require sophisticated technologies to be produced, unless we can propose a low-tech way of constructing them. One way or another, these low-tech methods are most likely based on some form of modularization. Therefore, we lean on simple modules that can be laid out in multiple arrangements. The most familiar one of these modules is the humble brick. In that sense, Earth is a course about bricks and blocks. In other words, we strategically shift the complexity from the level of modules to the level of modular-configuration. To sharpen our strategy, we aim to minimize the number of modules and maximize the ways that modules can be assembled to ensure the ease of production without compromising the variety of the possible spaces that we can create from these modules. Interestingly, this approach not only works for approximation of optimal structural shapes but also for spatial layout of buildings and neighborhoods.

Similarly, we propose to structure the design process as a modular and discrete process such that one can continuously divide a task into smaller tasks up to the simplest computational tasks. Therefore, each one of these basic tasks can be carried out by utilizing fundamental computational methods. Consequently, aggregation of these basic computational methods can form sophisticated methods that carry out meaningful tasks within the design process. Of course, each design task may ask for a slightly different arrangement of the methods, but the fundamental methods remain the same; what changes is only their arrangement.

Such modularization inherently enables collaboration by explicating the reasoning and deduction processes. A designer can easily share a modular machine the community and get reflections, feedback,

or even contribution from them, much more easily than they could share a huge machine perfected for doing one thing. Naturally, the added transparency and clarity of a modular the design process will make it more easily explainable and thus provide for participatory design processes.

## 6. Outlook

Our outlook for the course is to become a virtual factory for collaboratively producing open-source computational methods, ideally all in Python. Our didactic and societal missions necessitate moving towards Open Source technologies instead of relying on proprietary platforms. In the last two decades, Python has become a dominant general-purpose scripting language. The simplicity of use and the closeness of the syntax to human language have made it an easy passage to the heart of the computational world, not only in computational design but also specially in computational science and engineering. Eventually the procedures developed for the course and those contributed by the students are to be made available through an online platform, accessible enough for the prospective inhabitants of the earth and masonry buildings to empower them for designing and engineering their homes, communal buildings, and neighborhoods.

## 7. Epilogue

The assumed chasm between earth architecture (that may be regarded as old-fashioned, down, or backward-oriented) with the most advanced computational methods for design and analysis is perhaps what makes this course fascinating for us, but in a subtle way that is challenging to explain. The great examples from the student projects as well as many instances of magnificent buildings listed as cultural heritage prove the opposite of such connotations in fact. However, this essay was to explain that not only this gap does not exist; there is in fact much methodological and technological content to explore and learn in this domain and many reasons to do this in such a sophisticated way. In any case, looking rigorously enough at any problem that may look like a simple problem will compel a humble and scientific attitude.

## 8. Acknowledgments

Earthy is a complex course brought into life by a team of diverse and complementary contributors. The authors would like to thank their colleagues and external collaborators from LEVS Architecten and ARUP Amsterdam for their genuine, valuable, and passionate contributions in devising, developing, and/or delivering the course. In particular, had it not been for the determination and commitment of Prof. Sevil Sariyildiz and Dr. Fred Veer to its didactic mission, this course would never have been authorized to exist.

Responsible Professor	Prof. Dr. Ir. Sevil Sariyildiz (TU Delft, Design Informatics)
Studio Director	Dr. Ir. P. Nourian (TU Delft, Design Informatics)
Instructors	Dr. Ir. Fred Veer (TU Delft, Structural Design & Mechanics) Ir. Hans Hoogenboom (TU Delft, Design Informatics) Ir. Dirk Rinze Visser (BURO HAPPOLD & TU Delft, Structural Design & Mechanics) Ir. Shervin Azadi (TU Delft, Design Informatics) Ir. Frank Schnater (TU Delft, Design of Construction)
Guest Lecturers	Ir. Juriaan van Stigt (LEVS Architecten) Dr. Michele Palmieri (ARUP Amsterdam) Ir. Koen Mulder (TU Delft, Design of Construction)

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## 10. Endnotes

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I I would definitely suggest the readers to watch the movie *Hidden Figures*, based on the historical story of a group of female African-American mathematicians who were hired in NASA to work as 'secretaries' in order to 'type code' or double check the calculations done by machines in 1960's. Remember that it was not until 1968-1970 that the despicable laws of racial segregation in the US were finally abolished.

II It must be noted that in several similar occasions, refugees are not allowed to make permanent structures because they are supposed to leave their camp once the problems behind their displacement are resolved. However, in reality, many refugee camps, which are politically supposed to be temporary, end up being used for many years, long enough for a generation of people to be born and raised in the camp. Of course, the rapid set up of such camps by UNHCR and local authorities is certainly admirable,

III One challenge typically associated with earth architecture, due to the lack of tensile resistance in masonry materials, is the vulnerability of earthen buildings against earthquakes, most tragically manifested in the recent earthquake at the city of Bam, killing many people mostly entrapped under earthen rubble, and destroying much of the largest earthen building on earth, the Citadel of Bam. This is to say that such problems cannot be underestimated; and so, we have always had a long lecture on earthquakes by a specialist on measures for strengthening earth buildings against earthquakes.

IV Prior to the widespread use of steel and flat glass in construction, i.e. the characteristics of modern architecture, windows and door openings used to be almost always narrow and "arched", and the shape of the roofs, especially in important buildings with a wide span used to be vaulted or domed. This tradition even survived the early modern movement as apparent in the shape of the roofs of many train stations built in Europe in the 18th and the 19th century.

V <http://www.instructables.com/id/How-to-Build-Dirt-Cheap-Houses/>

VI <https://www.colourbox.com/image/ancient-fisherman-s-wooden-hut-in-ethnic-park-of-alesund-norway-image-1723627>

VII <https://www.colourbox.com/image/ancient-fisherman-s-wooden-hut-in-ethnic-park-of-alesund-norway-image-1723627>

VIII <http://original.britannica.com/eb/art-322/Contrasting-triangles-in-Euclidean-elliptic-and-hyperbolic-spaces>

IX Interestingly, in the Netherlands, perhaps due to the windy climate, the so-called Hofjes are popular too.