Technical University of Munich
TUM Department of Architecture

Tenue Track Assistant Professorship Digital Fabrication
Associate Professorship of Architectural Design and Building Envelope
Chair of Building Technology and Climate Responsive Design

Module Summer Term 2020

Basics of Robotic Fabrication
Adaptive Building Envelopes

Climate Active Bricks

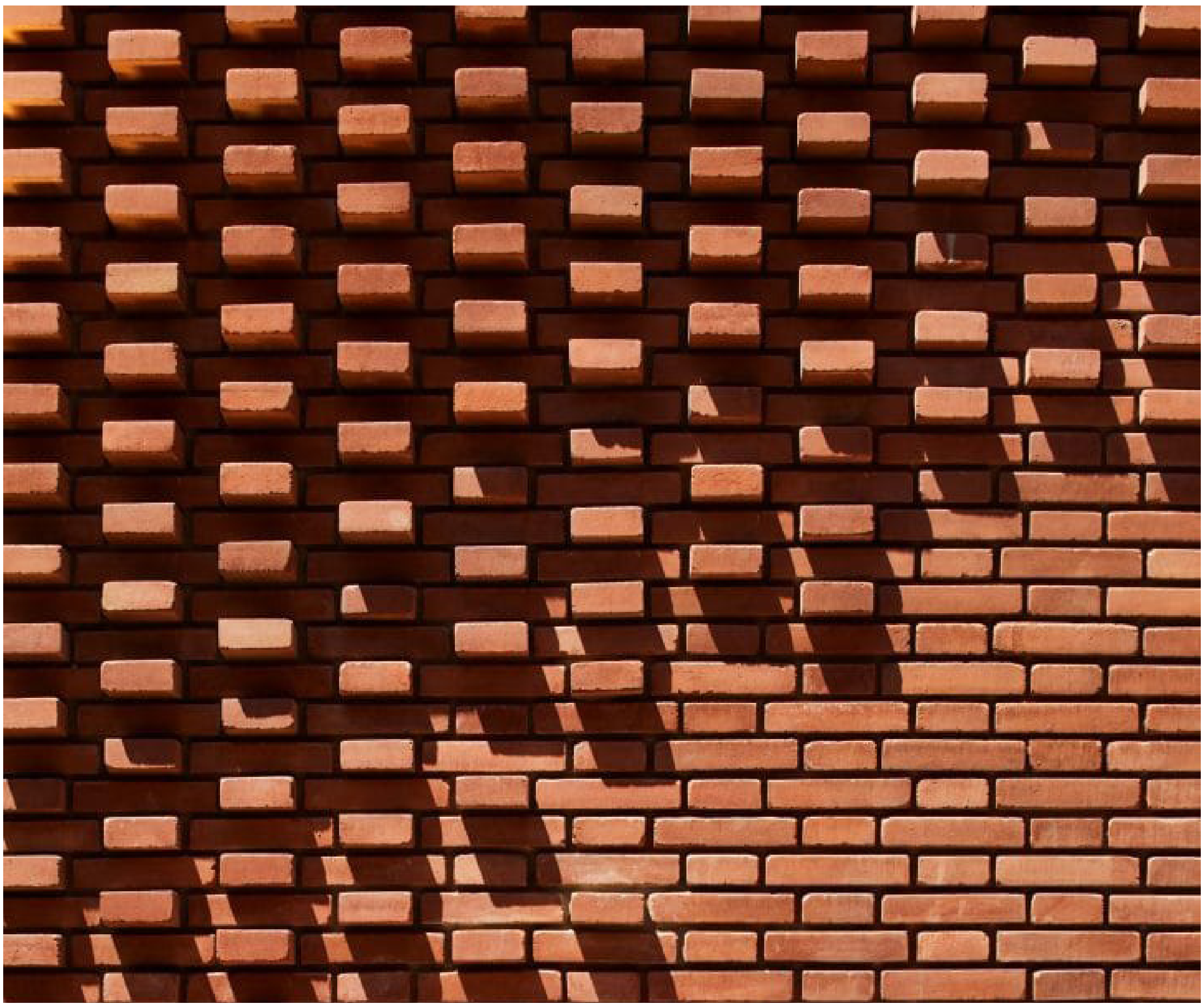

Image: Museum Yves Saint Laurent - Marrakech
Photo: Dan Glasser - Studio KO

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Climate Active Bricks
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Basics of Robotic Fabrication	6 ECTS
Adaptive Building Envelopes	6 ECTS

Kick Off
23.04.2020 | 09:45h | on Zoom

Thursday Jour Fixe

session 1	09:45h	- 12.00h
session 2	13:15h	- 16:30h

Submission/Examination Dates

Project Presentation 1	14.05.2020
Submission Expose Text	28.05.2020
Project Presentation 2	18.06.2020
Project Presentation 3	02.07.2020
Final Presentation	23.07.2020

TT Professorship Digital Fabrication
www.ar.tum.de/df/

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Chair of Building Technology and Climate
Responsive Design
https://www.ar.tum.de/klima/startseite/

M.Sc. Ata Chokhachian
ata.chokhachian@tum.de

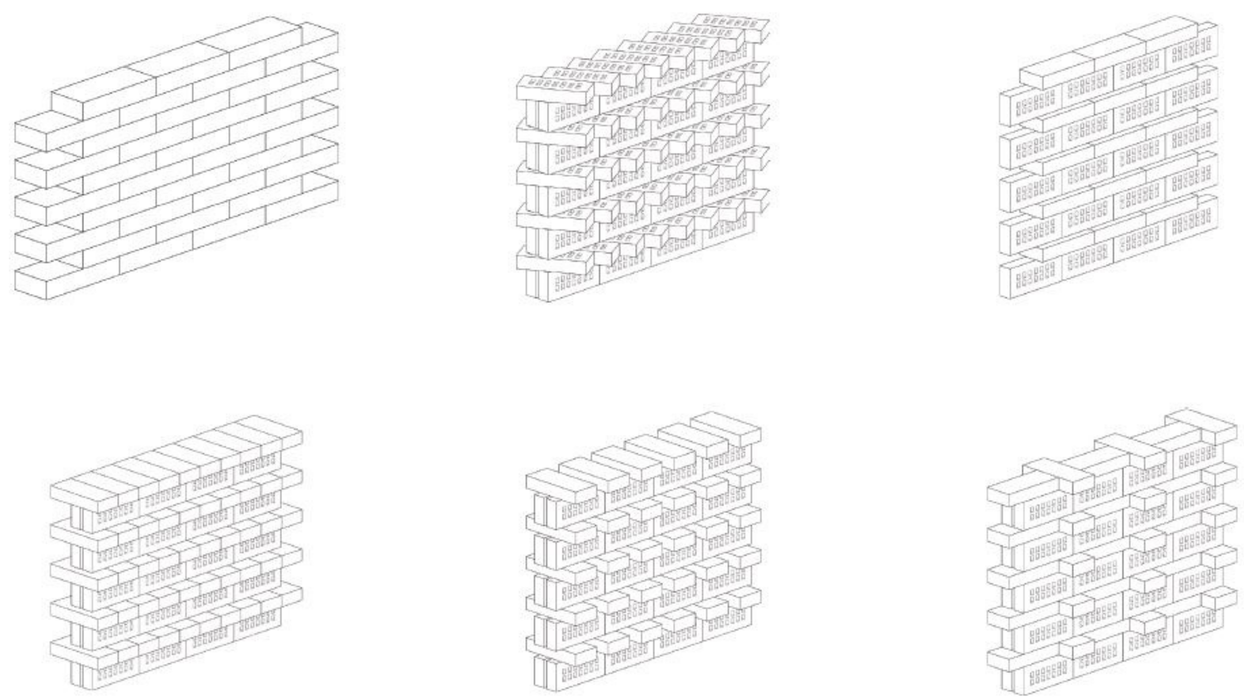


Diagram: Self shading brick patterns
Image: Associate Professorship of Architectural Design and Building Envelope - Sánchez, Aaron; Contreras, Andrea; Palacios, Sebastian; Bernabéu, Jaume; Sánchez, Beatriz; González, Eva

Building Envelopes and Impact on Microclimate

In the last centuries, history of human settlement was very much related to the use of brick as a key element for shelter as structure of architectural space (Serena, 2012). Since the very beginning of human settlement, sun dried mud and later burned bricks made out of clay have been used to build shelter and buildings all over the globe. The widely use of mud-bricks as a key element in prehistoric architecture and the following centuries is related to its modular and highly flexible use and adaptability to various applications allowing for a high degree of design freedom and structural performance (Oates, 1990). According to statistics in 1990, approximately 30% of the world's population lived in earthen brick made structures (Coffman, Agnewl, Austin, & Doehnel, 1990). In the last years brick architecture has experienced a revival and will grow even further. As said by Compound Annual Growth Rate, (CAGR) for the brick product segment the estima-tion is to raise 3.5% during 2017-2027 and it is anticipated to dominate over the forecast period (TMRGL, 2017). The mentioned advantages of brick construction are also subject of further research in digital fabrication with robots enabling ar-chitects to directly control complex geometries in construction. Due to its close relation to common construction practice, digital fabrication allows for the control of the micro and macro structure of a building component, per-formance optimization through the design of the cross section (Bonwetsch, Kobel, Gramazio, & Kohler, 2006). Therefore, this technology is supposed to increase the spread of brick construction in architectural context. However, since the 1980s, energy regulations have pushed the innovation of bricks towards better U-values especially in northern and central Europe. Thus, the latest developments have been pushed towards insulating bricks since they incorporate both the structural and the thermal functions of the building envelope (Wernery et al., 2017). The work of this research focuses on the potentials of brick as a climate active material improving urban (thermal) comfort conditions. Research and practice has already proved that brick is one of well performing material for climate control due to its high thermal capacity and thermal mass effect (Al-Sanea, Zedan, & Al-Hussain, 2012, 2013) nevertheless energy regulations have limited the innovation of bricks towards better thermal performance only. There have been various studies performed to understand thermal and optical performance of façade and pavement materials on microclimate of cities. The issue is important due to urban heat island phenomena described as temperature differences between downtown and suburbs. Due to decreased sky view factor in urban canyons as function of compactness and increased density of cities, the trapped heat and solar radiation keeps surface temperatures high even during night time. As consequence, the buildings that are dependent on night time cooling can-not recover and they cause significant health issues. The summer of 2003 could be relevant instance in Europe for the extreme heat wave that caused 15000 additional deaths in France (Ata Chokhachian, Santucci, & Auer, 2017).

The phenomena of urbanization and industrialization concerning its effect on environmental change has been known and studied for many centuries all over the world. Addressing the topic of environmental change, we need to refer to relevant metrics depending on the context and scale. Urban Heat Island effect (UHI) is one of the widely investigated phenomena to measure the effect of urbanization and built environment on the climate of cities. It is one of the most common manifestations on urban climate studies and since its advent by Luke Howard (1818), it is still the topic of researchers in different regions of the world. UHI by definition is known as higher temperatures or heat content stored in urban areas caused due to the anthropogenic heat released from vehicles, power plants, air conditioners and other heat sources, and due to the heat stored and re-radiated by massive and complex urban structures which leads to deterioration of living environment and increase in energy consumptions (Rizwan, Dennis, & Liu, 2008). As an example, Analysis of temperature trends for the last 100 years in several large U.S. cities indicate that, since 1940, temperatures in urban areas have increased by about 0.5 - 3.0 °C. Typically, electricity demand in cities increases by 2 - 4 % for each 1 °C increase in temperature. Hence, we estimate that 5 - 10 % of the current urban electricity demand is spent to cool buildings just to compensate for the increased 0.5 - 3.0 °C in urban temperatures (Akbari, Pomerantz, & Taha, 2001; Jandaghian & Akbari, 2018). It is found that for the city of Athens, where the mean heat island intensity exceeds 10 °C, the cooling load of urban buildings may be doubled, the peak electricity load for cooling purposes may be tripled especially for higher set point temperatures, while the minimum COP value of air conditioners may be decreased up to 25% because of the higher ambient temperatures (Mofidi & Akbari, 2017; Santamouris et al., 2001). There has been several approaches toward UHI mitigation by designing proportional aspect ratio for street canyons which allows enough sky exposure for night time cooling or choosing proper materials for building envelopes depending on context and orientation of each façade. Studies show that brick facades with low reflectivity in compar-ison with heavily insulated envelopes can decrease extreme heat stress for pedestrians by 26% during the day time (Ata Chokhachian, Perini, Dong, & Auer, 2017). Additionally, there has been several studies about evaporative cooling potential of building envelopes where Han, Xu, and Qing (2017) explored the effect of two passive cooling systems, water-retaining bricks on roof and radiation shield on roof concluding that the maximum cooling capabil-ity can be achieved through on-roof water-retaining bricks. Another study explores the effects of a Moist Void-brick wall as passive microclimatic converter and the results show that the wall surface temperature are averagely lower than ambient air temperature by 5 °C over day time (He & Liu, 2012). Addressing the wide spread of brick buildings as well as the mentioned problems with urban heat island and outdoor comfort, this paper proposes an architectural investigation on innovative approaches on the potentials of irrigated solid bricks as a component for climate adaptive facades. It is understood that the focus on this research is clearly an investigation as an architectural approach rather than an emphasis on building physics.

References

Akbari, H., Pomerantz, M., & Taha, H. (2001). Cool surfaces and shade trees to reduce energy use and improve air quality in urban areas. Solar Energy, 70(3), 295-310. doi: https://doi.org/10.1016/S0038-092X(00)00089-X

Al-Sanea, S. A., Zedan, M. F., & Al-Hussain, S. N. (2012). Effect of thermal mass on performance of insulated building walls and the concept of energy savings potential. Applied Energy, 89(1), 430-442. doi: https://doi.org/10.1016/j.apenergy.2011.08.009

Al-Sanea, S. A., Zedan, M. F., & Al-Hussain, S. N. (2013). Effect of masonry material and surface absorptivity on critical thermal mass in insulated building walls. Applied Energy, 102, 1063-1070. doi: https://doi.org/10.1016/j.apenergy.2012.06.016

Bonswetch, T., Kobel, D., Gramazio, F., & Kohler, M. (2006). The informed wall: applying additive digital fabrication techniques on architecture. Paper presented at the 25th Annual Conference of the Association for Computer-Aided Design in Architecture.

Cauvin, J. (2000). The Birth of the Gods and the Origins of Agriculture: Cambridge University Press.

Chokhachian, A., Perini, K., Dong, S., & Auer, T. (2017). How Material Performance of Building Façade Affect Urban Microclimate. Paper presented at the Powerskin 2017, Munich, Germany.

Chokhachian, A., Santucci, D., & Auer, T. (2017). A Human-Centered Approach to Enhance Urban Resilience, Implications and Application to Improve Outdoor Comfort in Dense Urban Spaces. Buildings, 7(4), 113.

Coffman, R., Agnewl, N., Austin, G., & Doehnel, E. (1990). ADOBE MINERALOGY: Characterization of Adobes from around the world. Paper presented at the 6th International Conference on the Conservation of Earthen Architecture: Adobe 90.

Friesem, D. E., Karkanas, P., Tsartsidou, G., & Shahack-Gross, R. (2014). Sedimentary processes involved in mud brick degradation in temperate environments: a micromorphological approach in an ethnoarchaeological context in northern Greece. Journal of Archaeological Science, 41, 556-567. doi: https://doi.org/10.1016/j.jas.2013.09.017

Han, R., Xu, Z., & Qing, Y. (2017). Study of Passive Evaporative Cooling Technique on Water-retaining Roof Brick. Procedia Engineering, 180, 986-992. doi: https://doi.org/10.1016/j.proeng.2017.04.258

He, J., & Liu, K. Q. (2012). Numerical Analysis of Passive Microclimatic-Modifying Effects of a Moist Void-Brick Wall. Applied Mechanics and Materials, 193-194, 1156-1164. doi: 10.4028/www.scientific.net/AMM.193-194.1156

Howard, L. (1818). The Climate of London: deduced from Meteorological observations, made at different places in the neighbourhood of the metropolis: W. Phillips, sold also by J. and A. Arch.

Jandaghian, Z., & Akbari, H. (2018). The effects of increasing surface reflectivity on heat-related mortality in Greater Montreal Area, Canada. Urban Climate, 25, 135-151. doi: https://doi.org/10.1016/j.uclim.2018.06.002

Künzel, H. M. (1994). Verfahren zur ein- und zweidimensionalen Berechnung des gekoppelten Wärme- und Feuchtetransports in Bauteilen mit einfachen Kennwerten. 42.

Lengsfeld, K., & Holm, A. (2007). Entwicklung und Validierung einer hygrothermischen Raumklima-Simulationssoftware WUFI®-Plus. Bauphysik, 29(3), 178-186. doi: doi:10.1002/bapi.200710025

Mofidi, F., & Akbari, H. (2017). Personalized energy costs and productivity optimization in offices. Energy and Buildings, 143, 173-190. doi: https://doi.org/10.1016/j.enbuild.2017.03.018

Oates, D. (1990). Innovations in mud-brick: Decorative and structural techniques in ancient Mesopotamia. World Archaeology, 21(3), 388-406. doi: 10.1080/00438243.1990.9980115

Rizwan, A. M., Dennis, L. Y. C., & Liu, C. (2008). A review on the generation, determination and mitigation of Urban Heat Island. Journal of Environmental Sciences, 20(1), 120-128. doi: https://doi.org/10.1016/S1001-0742(08)60019-4

Santamouris, M., Papanikolaou, N., Livada, I., Koronakis, I., Georgakis, C., Argiriou, A., & Assimakopoulos, D. N. (2001). On the impact of urban climate on the energy consumption of buildings. Solar Energy, 70(3), 201-216. doi: https://doi.org/10.1016/S0038-092X(00)00095-5

Schmandt-Besserat, D. (2015). The Beginnings of the Use of Clay in Turkey. Anatolian Studies, 27, 133-150. doi: 10.2307/3642659

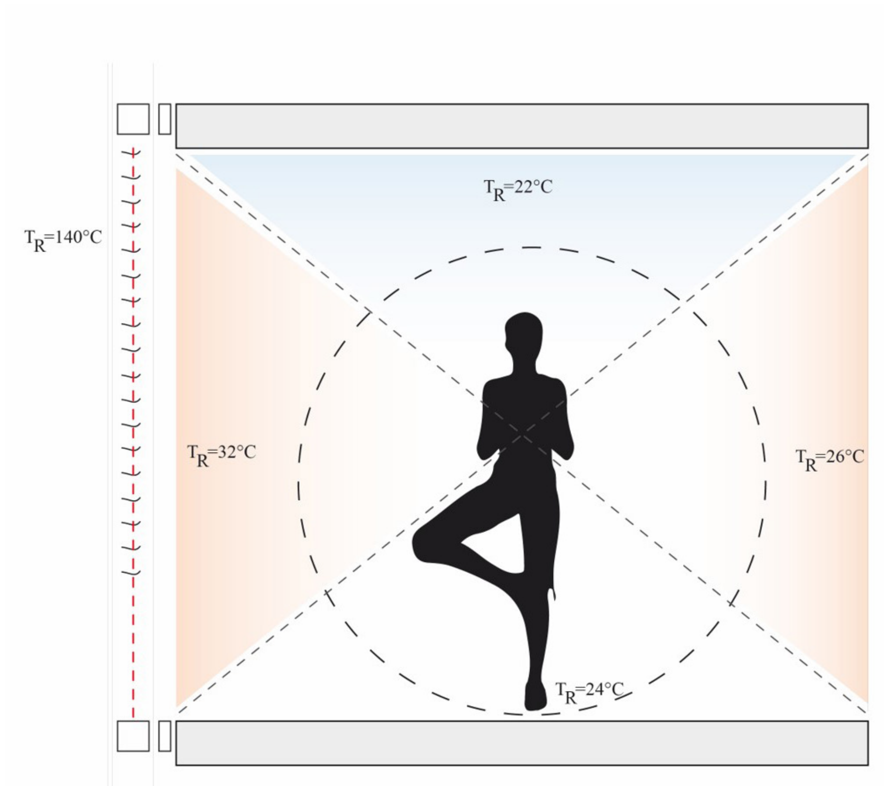
Serena, L. (2012). The Geoarchaeology of Mudbricks in Architecture: A Methodological Study from Çatalhöyük, Turkey. Geoarchaeology, 27(2), 140-156. doi: doi:10.1002/gea.21401

Stevanović, M. (1997). The Age of Clay: The Social Dynamics of House Destruction. Journal of Anthropological Archaeology, 16(4), 334-395. doi: https://doi.org/10.1006/jaar.1997.0310

TMRGL. (2017). Concrete Block and Brick Manufacturing Market (Product Type - Concrete Block (Hollow, Cellular, and Fully solid), Brick (Clay, Sand lime, and Fly ash clay), and ACC Block - Global Industry Analysis, Size, Share, Growth, Trends, and Forecast 2017 - 2027 (pp. 174): Transparency Market Research.

Uğurlu, E., & Böke, H. (2009). The use of brick–lime plasters and their relevance to climatic conditions of historic bath buildings. Construction and Building Materials, 23(6), 2442-2450. doi: https://doi.org/10.1016/j.conbuildmat.2008.10.005

Wernery, J., Ben-Ishai, A., Binder, B., & Brunner, S. (2017). Aerobrick — An aerogel-filled insulating brick. Energy Procedia, 134, 490-498. doi: https://doi.org/10.1016/j.egypro.2017.09.607



''Operative temperature'' DIN 7730 (perceived temperature): human beings are not only sensitive to the dry air-bulb temperature but also the air relative humidity, the mean radiant temperature, the air velocity and the personal clothing and activity level.

Diagram: Comfort temperatures and operative temperatures in an office with different heating methods. Image: https://www.researchgate.net/publication/290869207_Comfort_temperatures_and_operative_temperatures_in_an_office_with_different_heating_methods [accessed Feb 26 2020].

One of the main aspects of life is the dynamics of its elements. Climate conditions, behaviors and comfort.

The 'comfort' depends on personal perceptions and also on temporarily changing feelings of an individual user. It mainly consists of four comfort parameters:

- visual comfort
- thermal comfort
- acoustic comfort
- supply of fresh air

Those four comfort parameters are essential for human well-being and human health.

Visual Comfort: The visual comfort defines the conditions of the human environment in terms of lighting levels, glare, light distribution and light color. For the users the main aspects of visual comfort are:
- the comfort of human beings that provides the feeling of well-being
- the performance which enables working people to manage visual tasks even under difficult circumstances over a long time period. However, adequate supply of daylight is a very important component for human health and therefore the building envelope needs to provide precise regulation of glare, illuminance, brightness, luminous flux.

Acoustic Comfort is achieved when spaces provide appropriate acoustical support for interaction, confidentiality, and concentrative work and habitation by regulating noise levels, sound absorption, sound attenuation, sound insulation and reverberation time. The building envelope provides mostly high sound insulation from exterior to the interior of a building by using sound absorbing surface towards interior spaces.

Thermal Comfort: Thermal comfort is very much related to the air temperature as well surface temperature of our human body. It is further depending on physical activity, age, gender, surface temperatures, humidity, air speed and insulation between human body and surrounding space. Most of these parameters are significantly driven by the performance of the building envelope by Sun shading devices, thermal insulation materials, radiation reflecting or absorbing materials. (ASHRAE Stan-dard 1981) Thermal comfort in rooms depends partly upon radiative exchange between occupants and their surroundings. Thermal radiation has a major influence on the heat balance of humans.

Fresh Air Supply: besides human emissions of CO2 and humidity, gases, odours, biological impurities that transmit diseases, aerosols and dust require sufficient amount of approximately one volume exchange per hour of an internal space. This is a significant energy consuming part of a building. And since recent buildings tend to become more and more airtight, an autonomous decentralized ventilation system providing fresh air supply is the focus of various researchers working on adaptive building envelopes. However, the regulation of the above mentioned comfort parameters has been underestimated in the last decades.

At the same time the building envelope has not only an impact on its internal spaces but has also a major impact on its exterior environment: The façade (of lat .: facies:. Face) shapes the external appearance of a building and generates the expression of the essence of an edifice and determines outside comfort conditions.

Image: UR Robot Setup of the Augmented Fabrication Lab
Photo: TT Professorship Digital Fabrication

preface
- Basics of Robotic Fabrication

Prof. Dr. sc. ETH Kathrin Dörfler

The Tenure Track (TT) Professorship Digital Fabrication is a newly founded research group dedicated to the research and teaching of computational design and digital fabrication processes in architecture. Currently, the team of the Professorship consists of four research and teaching associates with different professional backgrounds. The research group's goal in teaching is to engage students in interdisciplinary thinking, merging the fields of architectural design, engineering, and construction, and to explore how computational design and new robotic fabrication technologies can lead to more efficient building construction and reduce the use of resources. Parametric and algorithmic design strategies provide a platform for exploration into the integrative use of computational processes in architectural design, with a particular focus on integrative methods for the generation, simulation and evaluation of highly performative material and building systems. With the use of mixed reality tools, the research group also explores the idea of a hybrid, dually augmented human-robot workforce aiming towards a fully integrated digital building culture. The TT Professorship is based at the Department of Architecture and affiliated with the Department of Civil, Geo and Environmental Engineering.

Seminars of the TT Assistant Professorship Digital Fabrication develop in relation to a task-specific scenario and a constructively motivated question regarding Architecture and Digital Fabrication. The analysis of the task and technological boundary conditions are as much the content of the design projects as the research of reference projects, the literature on the state of science and analysis on the topic, and the development of a structural and spatial concept, materiality, and architectural language. The focus is on the conception and elaboration of an architectural design, which is developed on the basis of concrete, exemplary studies and the further implemen-tation of prototypes on a model scale and exemplarily on a 1: 1 scale. Depending on the topic, the project may also have an interdisciplinary character and deal with topic-related contents of adjacent disciplines. The developed interdisciplinary topics are incorporated into the project investigations and support the design theses.

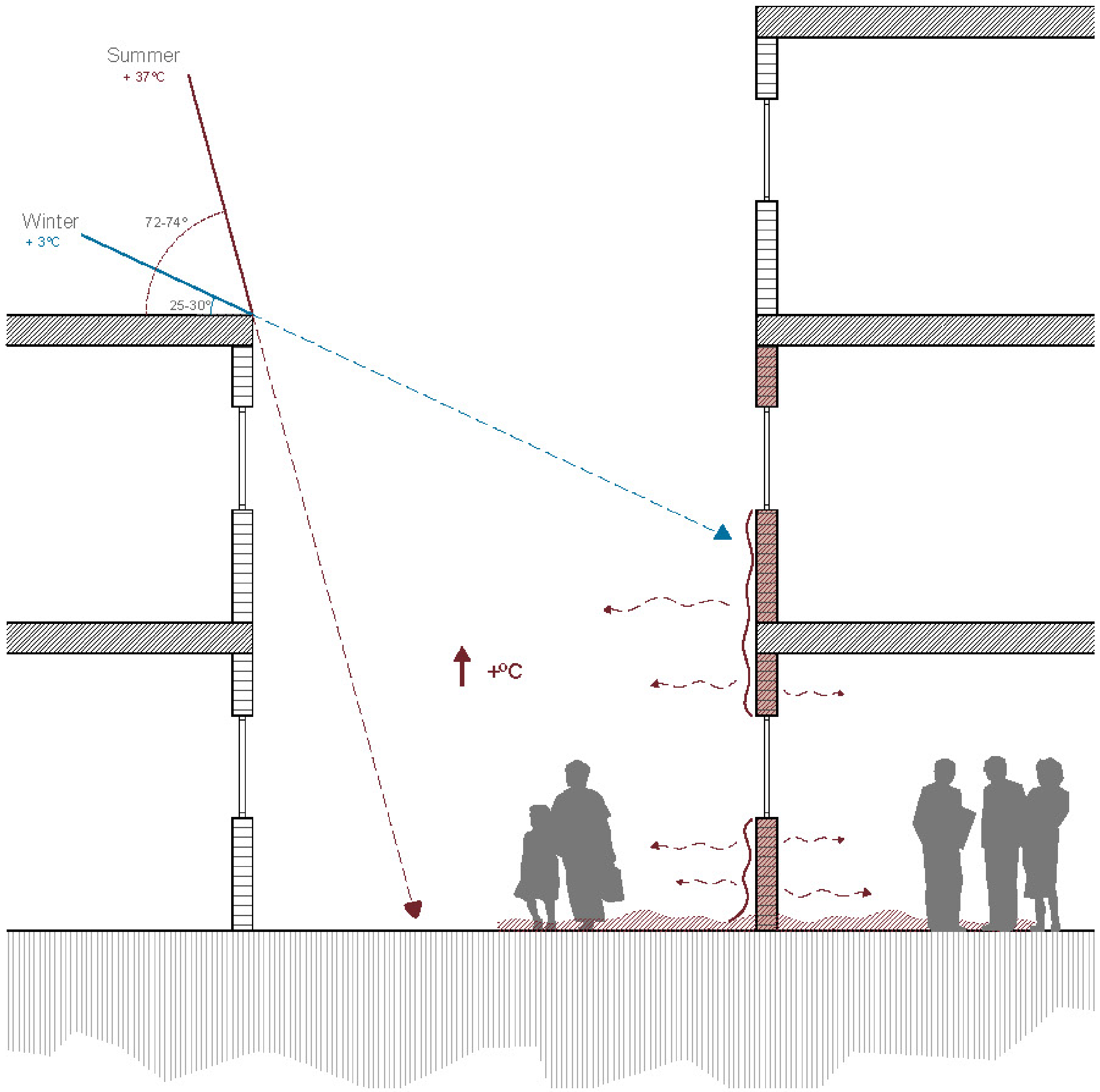


Diagram: Impact of materiality on urban micro climate
Image: Associate Professorship of Architectural Design and Building Envelope

Dr. - Ing. Philipp Lionel Molter

The Associate Professorship of Architectural Design and Building Envelope is part of the TUM Department of Architecture. It's interdisciplinary design approach in teaching and research:

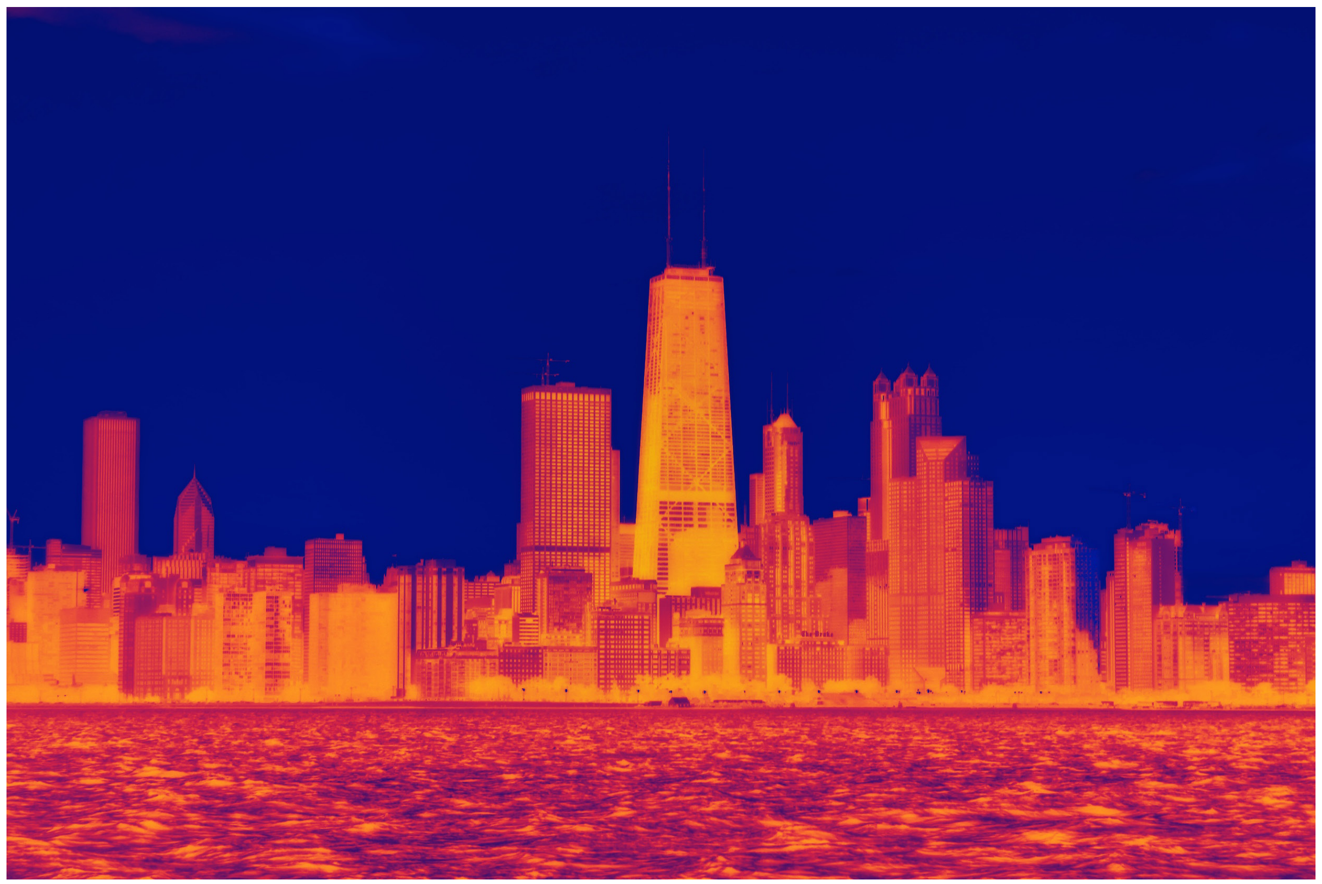
The focus area 'Experimental' investigates in architectural designs in the context of Additive Manufacturing focussing on 'functional geometries' for the building envelopes. The aim is to use advantages of digital fabrication and complex geometries in order to augment indoor and outdoor comfort and energy efficiency of buildings by reducing technical devices in the same time.

The focus area 'adaptation' researches in the ability of building envelopes to respond to exterior climate conditions. Just as our natural environment is in a constant process of adaptive change, architecture can adapt to climatic requirements. With nature as the model, the Associate Professorship of Architectural Design and Buildung Envelope developed building envelopes which, analogous to natural envelope systems, considered either diurnally or annually, behave adaptively and responsively.

M. Sc. Ata Chokhachian

The Chair for Building Technology and Climate Responsive Design is part of the Department of Architecture. Its core focus in teaching and research is a holistic design approach for buildings in consideration of the sustainability goals of the European Union (EU). A 90% reduction of CO_2 emissions in the building sector compared to 1990 is the main goal of the EU carbon roadmap.
The implementation of the carbon roadmap will have major impact on the built environment. The necessary transformation process goes hand in hand with the ongoing transformation in the wake of climate change and urbanization. In research the chair is dealing with transformations of the built environment and develops a holistic design approach hand in hand with architects, engineers and urban planners.
In the past, energy efficiency was primarily driven by technology. At the moment, however, there is a rethinking of more holistic concepts that increasingly incorporate the urban and regional scale. The overall objective of this approach is to create maximum comfort in the interior as well as in the exterior of the built environment while minimizing the use of resources at the same time.

The chair contributes through practice oriented research with two main focus areas: "Environmental Quality" and "Energy Management" tries to bring new insights in the holistic design approach for buildings and cities. Through this module we will explore environmental modeling tools to quantify local impacts of brick walls. We will use computational simulations to provide optimized alternatives for robotically manufacturing of brick elements. These tools will support us in the process of design and decision making to understand the microclimatic impacts on human scale.



Thermal simulation of Chicago, IL.
Image: Dustin Phillip, 2019

Thursday Jour Fixe	Session 1 - BE Session 2 - DF	9.45h - 12.00h 13.15h - 16.30h
23.04.2020	09.45h 13.15h	Kick Off and Introduction Lectures BE & DF Assignment of the Research Topic
30.04.2020	no Session	Field Trip Slot (for Design Studios)
07.05.2020	09.45h 13.15h	Session BE -Lecture "Performative Envelopes" Session DF: Getting Started with Python
14.05.2020	09.45h 13.15h	Project Presentation 1 (Research Idea) Session DF: Datastructures and Geometry
28.05.2020	09.45h	Submission of the Research Exposé Session DF: Datastructures for Robotic Fabrication
04.06.2020	09.45h 13.15h	Session BE: Lecture "Simulation of Thermal Comfort" by Ata Chokhachian Design Research Workshop with Deskcrit
18.06.2020	9.45h 13.15h	Project Presentation 2 (Design Concept) Session DF: Robotic Fabrication Basics
25.06.2020	9.45h 13.15h	Design Workshop with Deskcrit Design Workshop with Deskcrit

Phase 1
Research-by-Design Phase

02.07.2020	9.45h 13.15h	Project Presentation 3 (Design Completed) Session DF: Fabrication Workshop
09.07.2020	9.45h	All-day Fabrication Workshop
16.07.2020	9.45h	All-day Fabrication Workshop
23.07.2020	9.45h	Final Presentation (Fabrication Completed)
28.07.2020		Submission of Project Documentation

Phase 2
Production Phase

Module Objective

The module Climate Active Bricks will examine the microclimate effects of differentiated geometries of brick structures. Through this course, we will explore environmental modeling tools to quantify local climatic impacts of brick walls onto their immediate surrounding. We will use simulation data to support us in the process of design and decision making for spatial brick structures with the aim to improve human comfort. Finally, we will use robots for the fabrication of intricate designs.

Module Structure
The module consists of two main phases

Phase 1 — Research-by-Design Phase
Developing a Research Topic
Working on a Design Task
Exploring digital Design Tools

Phase 2 — Production Phase
Fabrication of selected demonstrator objects

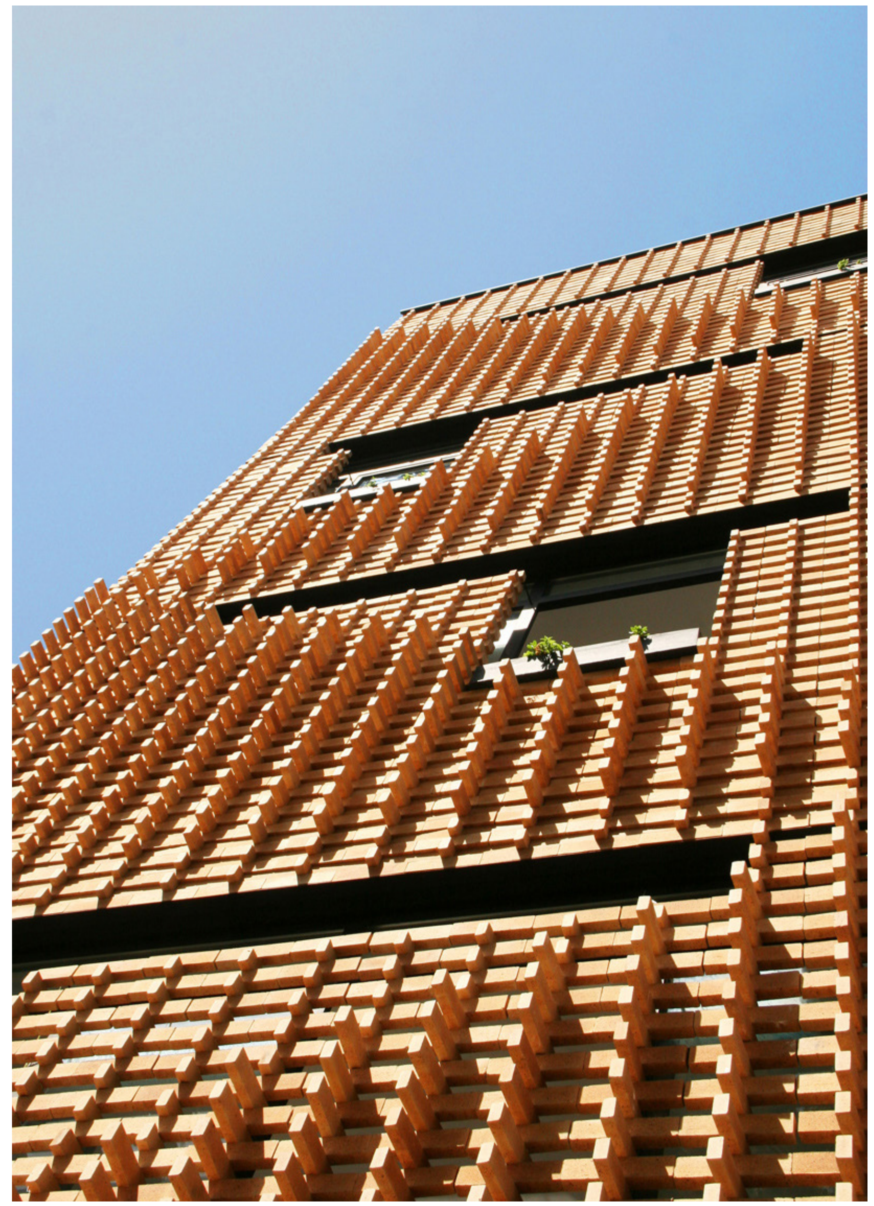


Image: Brick Pattern House by Alireza Mashhadimirza
Photo: Alireza Mashhadimirza

Graphic: Climate-Active Furniture
Image: Associate Professorship of Architectural Design and Building Envelope -
Bareiss, Philippe; Bavshi, Harsh; Narayan, Keshav; Panchal, Himadri, Spiessens, Mathias

Phase 1 —
Research-by-Design Phase
Working on a design task
Developing a research topic
Exploring digital design tools

Design Brief:

Our objective for this semester's module is to design and develop a **spatial urban microclimate intervention (**walk-in structure) for central Munich made out of bricks. We imagine such a structure to become a space for exploration for your research on urban microclimate effects with a special focus on:

- issues of thermal comfort (urban heating/cooling islands)
- enhanced microclimate by various methods (e.g., self-shading by geometry, evaporation cooling, etc.)
- digital modeling, simulation, optimization, and assembly techniques

Research Exposé Structure

Introduction
Background and motivation: Introduction to the topic being studied and the importance of it (e.g. aspects of societal relevance: economic growth, demographic development, environmental impact, etc.). A clear and concise summary of the whole research objectives.

State of the Art
A short description of relevant research in the field that provides context to your own work: Statement about an area of concern, a condition to be improved upon, a difficulty to be eliminated. Places the problem into a particular context. Does not state how to do something, nor does it offer a vague or broad proposition or present a value question Importance: When understanding the nature of the problem, one is better able to develop a solution. It determines where and what kind of research the writer will be looking for. It guides information to be collected.

Research and Design Objective
Identification of research gap/ problem statement, and specification of research and design question and goals:

Narrows down the focus. Guides information to be collected. Facilitates development of methodology. Can break down a broad objective into small logically connected parts. Is related to the problem of a study.

Method
A concise description of how you will conduct the research project. Which material, tools, location, effect will you apply?

- Selection of procedures and research instruments
- Method for data collection and analysis

Expected Results
Describe expected research findings and what you want to verify/achieve. Be precise in regard to what you want to test digitally as well as physically:

- Restate your thesis
- Summarize your main findings
- Answer the research questions

References
Your literature sources

Phase 1 —
Research-by-Design Phase
Working on a design task
Developing a research topic
Exploring digital design tools

Image:
Courant D'Air by Océane Romanet

Developing a Research Topic

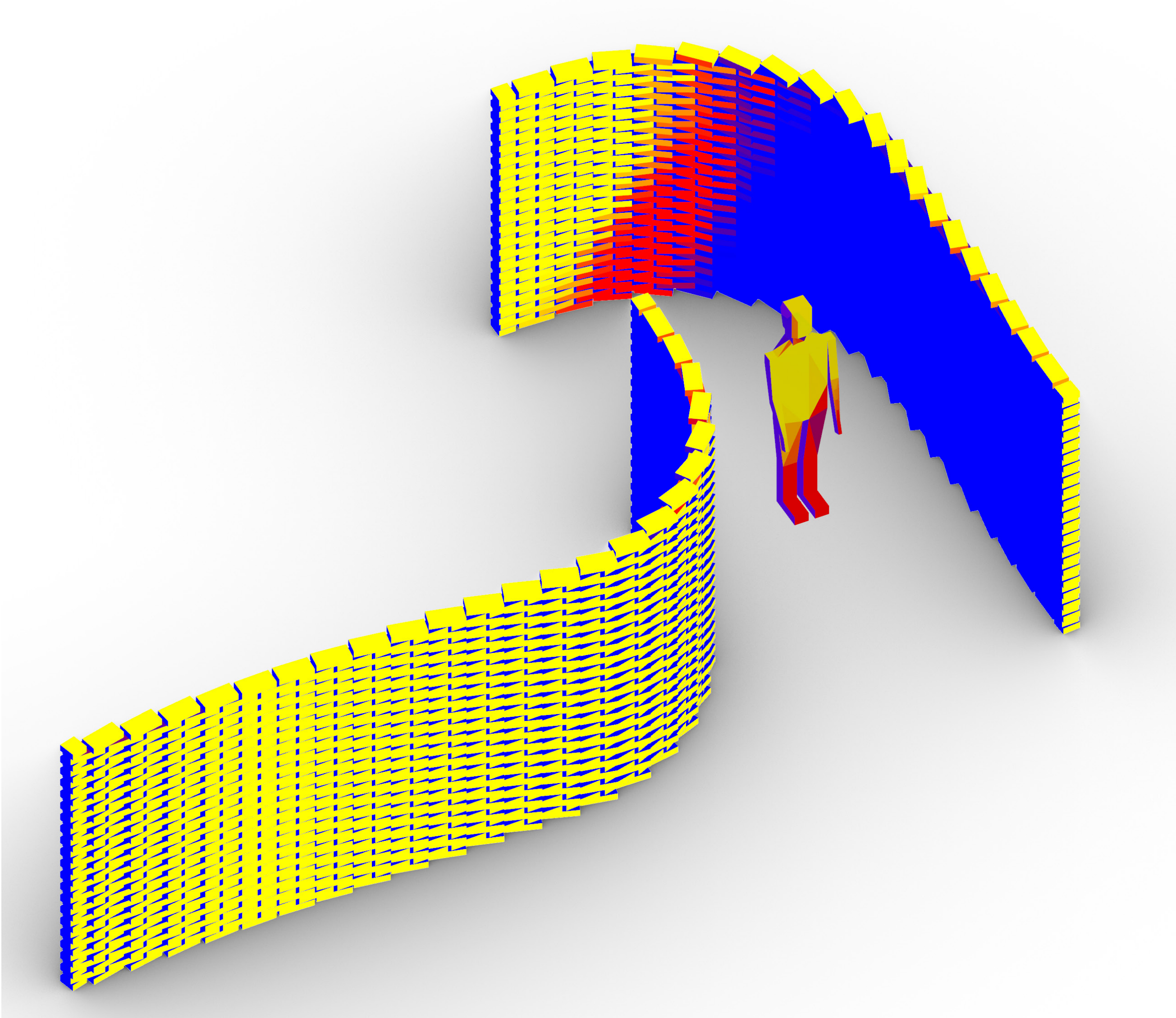
Your scientific investigation should focus on strategies for augmenting the performances of your urban intervention by responding to the surrounding climate conditions. In order to develop your design proposal an in-depth research could be accomplished in one of the following topics:

- Urban heat island effect
- Urban microclimate effects
- Outdoor comfort in urban areas
- (Digital) brick design
- Robotic brickwork
- Self-shading geometries in (brick) facades
- Irrigated facade systems
- Evapotranspiration
- Autoreactive Systems
- etc.

Writing a Research Exposé

Your research exposé in the form of a presentation and text submission will describe your design proposal and associated research topic. For this use please the templates we provide you on Moodle.

We encourage you to sign up for the Climate Active Bricks Group on Mendeley for collaboration, exchange and development of our literature pool collection.



Simulation: Environmental Analysis and Optimization using Ladybug Tool
Image: Ata Chokhachian

Phase 1 —
Research-by-Design Phase
Working on a design task
Developing a research topic
Exploring digital design tools

Exploring Digital Design Tools

Based on your designs you will learn the principles of parametric and algorithmic design with the Rhino and Grasshopper software and the Python programming language.

To help you evaluating your designs we will explore environmental modeling tools to quantify local climatic impacts of brick walls onto their immediate surrounding. We will use simulation data to support us in the process of design and decision making for spatial brick structures with the aim to improve human comfort. We will also use robotic fabrication simulation tools to verify the fabricability of your designs.

The intended learning outcomes include:

- to understand the theoretical background of basic data structures,
- apply the basic principles of algorithmic design,
- implement basic versions of prevalent algorithms related to architectural geometry and robotic fabrication,
- use common CAD tools as interfaces to self-implemented solutions, and
- understand the scope and relevance of computational methods for architectural research and practice.

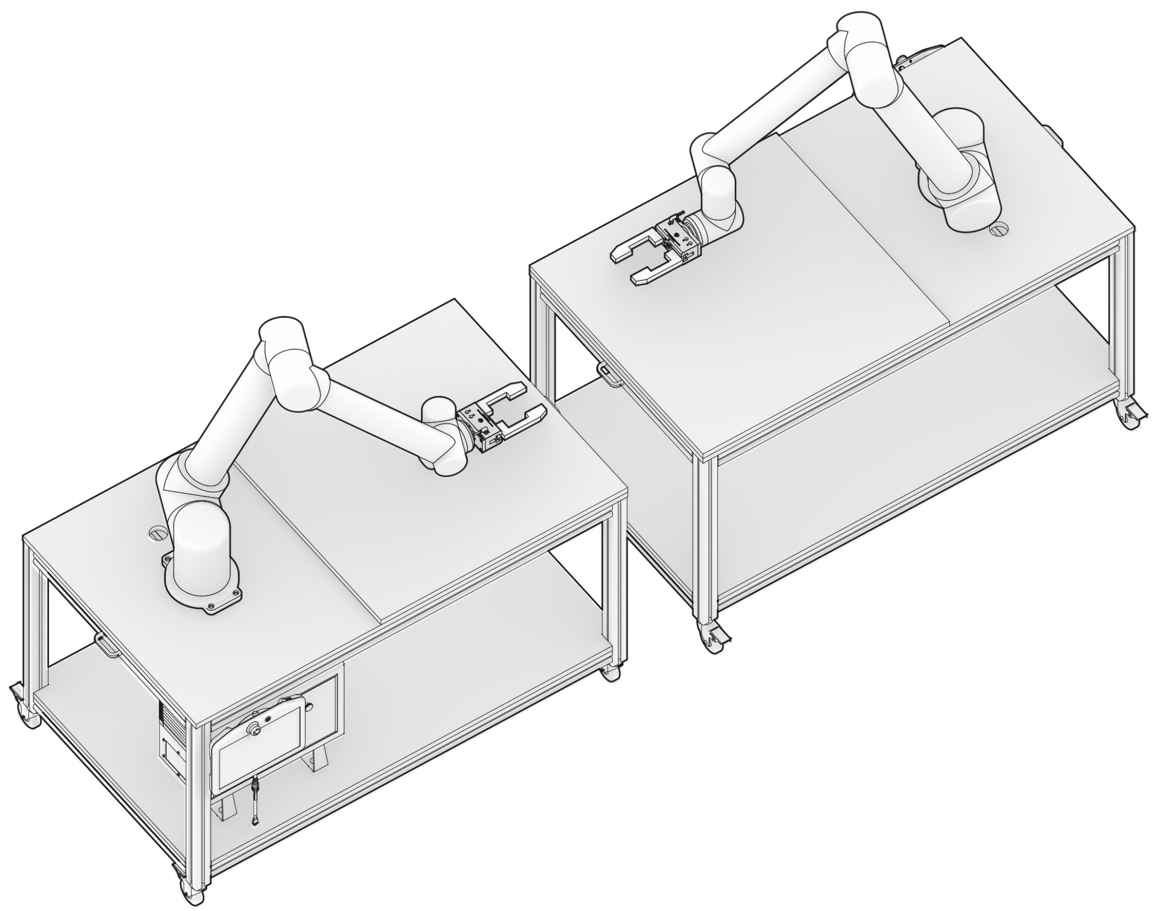


Illustration: Robot setup for the practical experimentation with concepts of robotic fabrication in architecture
Image: TT Professorship Digital Fabrication

Phase 2 —
Production Phase
Fabrication of selected demonstrator objects

Fabrication of selected demonstrator objects

In the center of phase 2 is the practical realisation of selected design proposals by using industrial robot arms to assemble the brick structures. By this we will explore their inherent process-distinct materiality, architectural expression and microclimate effects at a 1 to 1 scale.

Module Organisation

Online Tools
Webinars
- via Zoom

Module Material
- Moodle
- Github
- Mendeley

File Submission
- Moodle
- Google Drive

Module Requirements

Operating System
- Windows 10 Pro
  (freely available for all
  TUM students)

Commercial Software
- Rhinoceros 3D 6.0
  (test version is free for 90 days)

Text and Concept

TUM Department of Architecture
Technical University of Munich

TT Professorship Digital Fabrication

Associate Professorship of
Architectural Design and Building
Envelope

Chair of Building Technology and
Climate Responsive Design

Arcisstraße 21
80333 Munich I Germany

Climate Active Bricks

TUM Department of Architecture
Technical University of Munich

Tenue Track Assistant Professorship Digital Fabrication
Associate Professorship of Architectural Design and Building Envelope
Chair of Building Technology and Climate Responsive Design