BE-AM

Built Environment
Additive Manufacturing

DDU
Digital Design Unit — Digitales Gestalten

ISM+D
Institute of Structural Mechanics and Design
Institut für Statik und Konstruktion

FORUM
INTERDISZIPLINÄRE
FORSCHUNG

TECHNISCHE
UNIVERSITÄT
DARMSTADT

cover photo: Bayu Prayudhi | MSc Project | TU Delft

BE-AM 2017 is a collaboration of

ISM+D
Institute of Structural Mechanics and Design
Institut für Statik und Konstruktion

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Digital Design Unit — Digitales Gestalten

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Built Environment
Additive Manufacturing

BE-AM 2017
SYMPOSIUM FOR ADDITIVE MANUFACTURING IN BUILDING
FR. 27.10.2017 10:00 -17:00

BE-AM is an annual symposium on the theme of Additive Manufacturing in the Built Environment. The 2017 edition focuses on initiating discussions and exchange between experts from academia and industry on novel concepts and cutting-edge research in the context of additive manufacturing .

TU DARMSTADT | DDU + ISMD
EL-LISSITZKY-STRASSE 1 | BUILDING L3 - 01 | LECTURE HALL 98

WWW.DDU-RESEARCH.COM/BE-AM-2017

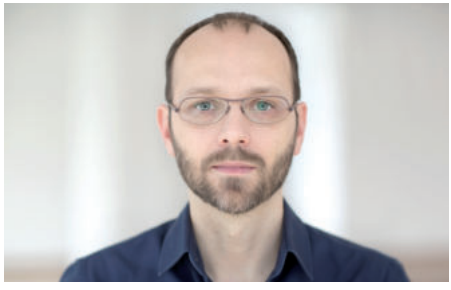
Symposium Chairs

Prof. Dr.-Ing. Ulrich Knaack

TU Darmstadt
Fachgebiet Fassadentechnik
Institut für Statik und Konstruktion

Fachbereich Bau- und Umweltingenieurwissenschaften (FB 13)

www.ismd.tu-darmstadt.de



Prof. Dr.-Ing. Oliver Tessmann

TU Darmstadt
Fachgebiet Digitales Gestalten
Digital Design Unit

Fachbereich Architektur (FB 15)

www.ddu-research.com

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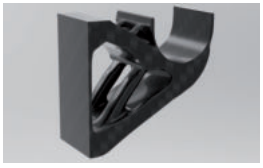
BE-AM 2017 | Program | Fr. 27.10.2017 | 10:00-17:00

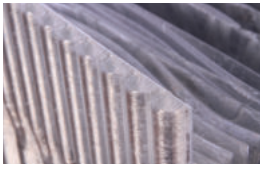
WELCOME

Prof. Ulrich Knaack and Prof. Oliver Tessmann
10:00-10:15

KEYNOTE
Prof. Andreas Trummer | TU GRAZ
Shells - State of the Art vs. Research
10:20-11:00



Prof. Jörg Lange | IFSW
AM in Steel
11:05-11:20

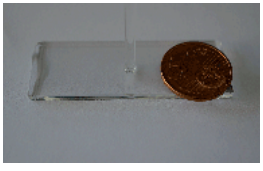


Valentini Sarakinioti | TU DELFT
SPONG3D: Developing an Integrated 3D-printed Façade for Active Control in Complex Geometries
11:25-11:40

COFFEE

Coffee Break 11:40-12:00

Andrea Rossi | DDU
Digitalizing Digital Fabrication – From Analog Production to Digital Assembly
12:00-12:15



Matthias Seel | MPA-IFW | Robert Akerboom | ISMD
Exploring the Potential of Additive Manufacturing with Glass for Application in the Built Environment
12:20-12:35

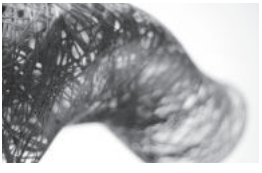
Prof. Samuel Schabel | Heinz-Joachim Schaffrath | PMV
Additive Manufacturing with Renewable Material Only
12:40-12:55

LUNCH

Lunch Break 12:55-14:10

Alamir Mohsen | ISMD
Steel Knots Newly Engineered
14:10-14:25

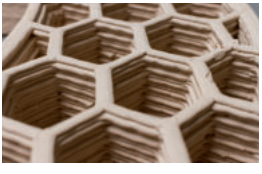
Christopher Borg Costanzi | ISMD
AM4AE : An Overview of Additive Manufacturing in Construction
14:30-14:45



Javid Jooshesh| TU DELFT
AM for Optimised Fibre-reinforced Ultra-lightweight Facade Elements
14:50-15:05

COFFEE

Coffee Break 15:05-15:30



Dennis de Witte | ISMD
Brick 2.0 Status
15:30-15:45

Prof. Oliver Tessmann | DDU
20.000 Blocks
15:50-16:05

KEYNOTE
Dr. Michela Turrin | TU DELFT
Performative Geometric Complexities
16:10-16:50

DISCUSSION

Closing Discussion

photo: Andreas Trummer

Assoc. Prof. Andreas Trummer | TU GRAZ

Andreas Trummer is an associate professor for structural design and robot-supported fabrication at the Institute for Structural Design at the Graz University of Technology, where he completed his civil engineering studies. In 2002 he received his doctorate from the University of Natural Sciences in Vienna. In 2009, he set up the robot design laboratory and thus focused his research on the digital fabrication of load-bearing components. His current research projects are devoted to questions about prefabricated shell structures, the "Ceramic Shell" project and the future of 3D-printing with concrete.

photo: Andreas Trummer

Shells - State of the Art vs. Research

Grid shells are currently very convincing due to their high level of transparency and the variety of possible geometries. Highest level digital geometry development, parametric workshop planning as well as high-precision milled individual parts form the basis for the steel structures, which is why it is considered high tech. This is the point where the differences, when compared to concrete and reinforced concrete construction, are very large. The expressive concrete shells of the 60's and 70's have almost disappeared from recent architecture. This is usually accounted to the complexity of the formwork; a look back in history shows the creativity used in the search for a suitable construction method.

The Institute of Structural Design is dedicated to the research of filigree concrete parts and the optimal use of the material beyond traditional production methods. After investigating thin-walled double-curved prefabricated elements, examining robot-supported extrusion processes and their potential for the mass production of concrete elements, new design possibilities within architecture and engineering were opened up.

photo: Alamir Mohsen

Alamir Mohsen | TU DARMSTADT | ISMD

Alamir Mohsen is educated as an architect, finished his Master degree in façade engineering from University of Applied Sciences in Detmold, Germany. Prior to his employment as a research assistant at TU Darmstadt where he started his Ph.D. studies, he has been working as a facade engineer with Bollinger + Grohmann Ingenieur and works as a writer for Facadeworld.

photo: Alamir Mohsen

Steel Knots Newly Engineered

Liaising between architect, facade engineer and manufacturer to achieve some middle ground where compromises are kept to a minimum will be an optimal step to grant a smooth transition from the design phase to the construction phase.
The power of parametric design is increasing, and the gap between design and construction is becoming bigger. A solution is needed to help to fill that gap and create a symbiotic relationship.
The search for a parametric node that can ease the process of façade construction is feasible but still needs to be developed from an idea to a product.
The limitation of offering a product with narrow possibilities is not agile in a world, where architects strive for innovative and unique designs.

Utilizing 3D printing is a powerful addition to speeding up the process, but the high cost is still a barrier, as well extracting the nodes' geometry as unique parts are not the best way to solve this dilemma.
Any successful product needs to be standardized even to some degree to benefit from the advantage of cost reduction and could be seen as a norm.
The material properties of 3D printed parts are yet to be defined to make the parts trusted enough to be utilized in the construction world.
The results so far are showing promising potential to reach the target of the research. Many factors need yet to be observed and investigated.

photo: Andrea Rossi

Andrea Rossi | TU DARMSTADT | DDU

Andrea Rossi (TU Darmstadt – Digital Design Unit) is computational designer and researcher, currently PhD candidate at the DDU Digital Design Unit - TU Darmstadt. His current focus is on the integration of research on robotic assembly and digital materials within architectural production strategies. His current and past research spans from robotic fabrication to computational urban planning, and his collaborations include ETH Zurich, Coop Himmelb(l)au, IndexLab - Politecnico di Milano, SenseLab, Kaminiarz&Cie among others. He has been lecturing and teaching workshops on computational tools in Italy, Germany, China and USA. His work has been presented extensively, including CAADRIA 2017, eCAADe 2017, IASS 2017, ACADIA 2013, EnCodingArchitecture 2013 Venice Biennale 2012. He has been co-chairing the symposium "Architectural Ecologies – Code, Culture & Technology" at EMCSR 2014.

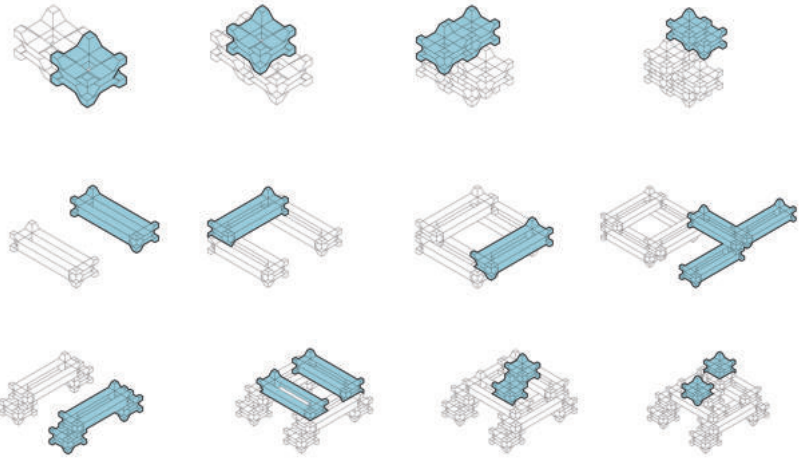


photo: Andrea Rossi

Digitalizing Digital Fabrication – From Analog Production to Digital Assembly

Current research at the DDU Digital Design Unit attempts to apply the potential of digital tools for their integration into wider and more democratic production networks. In his research, Andrea Rossi applies such approach to the realm of discrete design and robotic assembly, conceptualizing architectural formations as spatial assemblies of discrete building blocks to be aggregated through custom robotic procedures. The aim of such strategies is to create a more direct connection between design and fabrication, relying on the idea of discrete elements assembly and on the parallel between modular design and modularized robot code generation. This offers possibilities for overcoming the need for translation between digital design and analog manufacturing, as well as providing a compact procedure to represent both geometry and assembly information.

photo: Chris Borg Costanzi

Chris Borg Costanzi | TU DARMSTADT | ISMD

Chris completed a 5-year Bachelor in Architecture and Civil Engineering at the University of Malta in 2012. In 2016 he received a Master's Degree from Delft Technical University, specializing in concrete AM. Chris' interests lie in the threshold between Architecture, Engineering and Fabrication, sparked off after attending AA Visiting School in 2012 and whilst working as an architect before moving to Delft. During this period he worked on the design and fabrication of hardstone projects, including Renzo Piano's Parliament in Valletta. It was also during this time that he worked at Dfab Studio, under the guidance of Steve Demicoli (PhD cand. ICD, BSc Arch., AA). Prior to moving to Darmstadt, Chris undertook a 4TU project with TU Delft and TU Eindhoven for a concrete AM shell structure. He currently works at the ISM+D Department at TU Darmstadt and Imagine Structure, Frankfurt.

AM4AE

TECHNISCHE UNIVERSITÄT DARMSTADT
ISM+D Institute of Structural Mechanics and Design Institut für Statik und Konstruktion
IFSW Institut für Strahlwerkzeuge und Werkstofftechnik
INSTITUT FÜR WERKSTOFFE IM BAUWESEN

photo: Chris Borg Costanzi

AM4AE : An Overview of Additive Manufacturing in Construction

Documentation of the rapid growth of AM in the construction sector is generally done by means of social media groups and individual hobbyists that are interested in particular themes. AM4AE is an online database which seeks to document, analyse and share all past and current projects relating to AM in construction under one umbrella group. The primary use of the database is for the collection of statistical data which allow for an accurate representation of the state of AM within this theme. Projects are organized in multiple categories such as Materials, Themes and Printing Principles, allowing for a multitude of data levels to be presented. This allows for the identification of trends within the construction industry as well as themes common with other industrial groups. Ultimately, AM4AE aims to allow for more efficient sharing of knowledge between parties interested in the advancement of Additive Manufacturing at an industrial level.

Dennis de Witte | TU DARMSTADT | ISMD

DENNIS DE WITTE (*1988) completed his Master degree in Building Technology at Delft University of Technology, Netherlands in 2015, upon which he became a research associate under the supervision of Prof. Ulrich Knaack in Germany. To obtain his doctoral degree at TU Darmstadt, Faculty of Civil Engineering, he is investigating ways of implementing additively manufactured ceramic components within the built environment.
During his studies he was already involved in education and worked as student assistant at the University, chair of Design of Construction in Delft. In parallel to his work in Darmstadt he continued working part time on research into additive manufacturing in Delft for two years. In Darmstadt his research on “how materials and additive production processes match and how a variety of products perform within our built environment” continues.

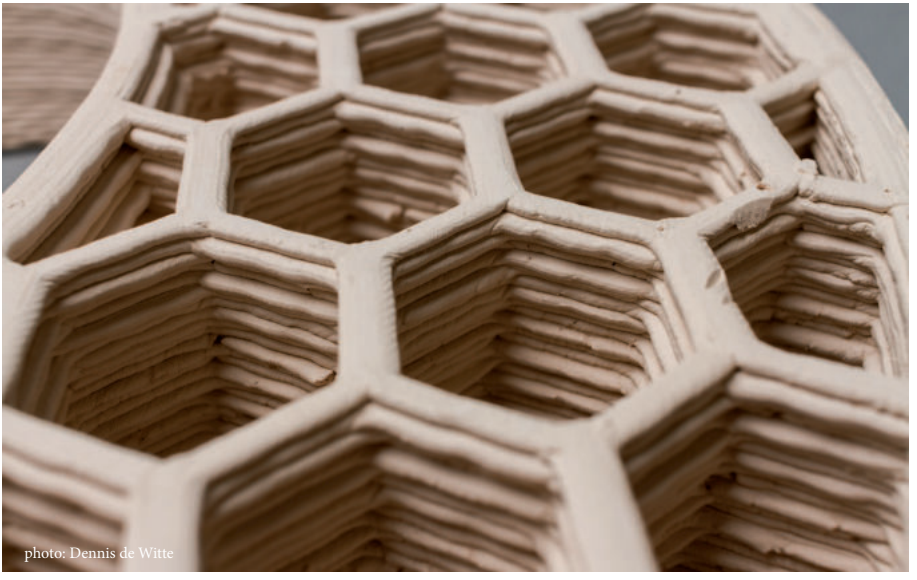


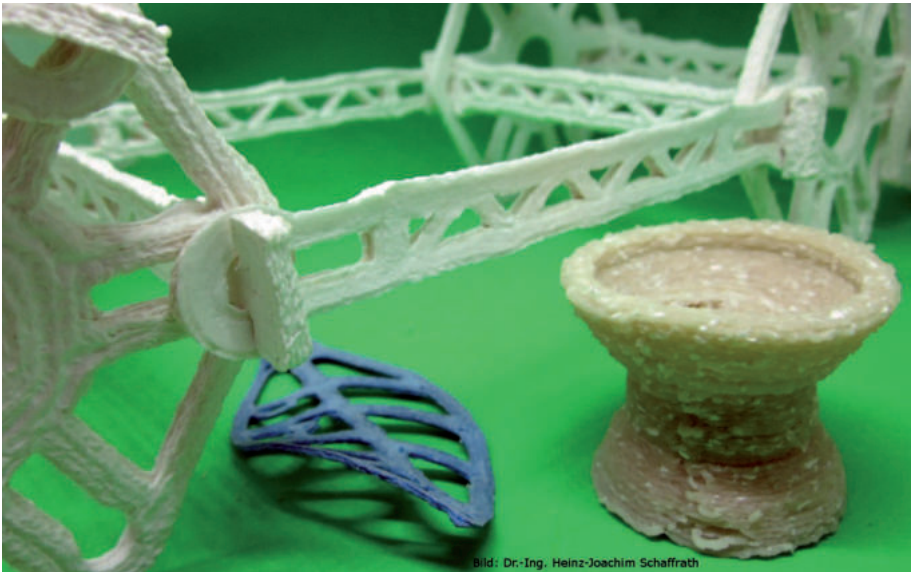
photo: Dennis de Witte

Brick 2.0 Status

The bricks 2.0 project focusses mainly on the application of 3D printed clay products. The idea to print clayey ceramics came with the aim to improve existing building products, but also with the aim to increase the variety of clayey ceramic building products.
Products that can be made of ceramic brickwork include free form elements, façade cladding and corner solutions. Products that cannot be made with a traditional formwork or extrusion process are up most interesting. Internal three-dimensional geometry is an example of that.
Challenging is how the material behaves in the production process and how a constant quality with changing geometries can be achieved. To get a general understanding of the fail mechanism of the clay products some compression and bending tests are performed at ISMD.

Dr. Heinz-Joachim Schaffrath | TU DARMSTADT | PMV

Heinz-Joachim Schaffrath, born in 1962, studied mechanical engineering and paper process engineering at the Technical University of Darmstadt and at École Française de Papeterie, Grenoble. After his diploma in 1988 he continued at TU Darmstadt and completed his doctor thesis on winding of paper reels. Since 1993 he worked in the German paper industry as project leader, mill manager and mill director for three different paper manufacturing companies.
When he returned to research in 2010 he took over the general management of a research company closely related to TU Darmstadt. This institute was integrated into the institute for Paper Technology and Mechanical Process engineering, where he is now responsible for industrial research projects, the paper testing laboratory and the research group dealing with paper physics.
Dr. Schaffrath is author of scientific publications in different fields of paper physics and paper properties, and author of topics in scientific books. In 2016 he organized the international Progress in Paper Physics Seminar. He is member of the DIN board for paper standardisation and nominated expert in ISO.
At TU Darmstadt he is teaching the subjects “Paper Testing” and “Paper Converting”.



Additive Manufacturing with Renewable Material Only

Additive manufacturing has an intrinsic environmental advantage compared to conventional manufacturing processes: material is brought to the place where it is needed and not removed by creating waste at the same time. This inspired the author to think how paper fibres, made from renewable wood fibres, could be used in additive manufacturing processes. In general, the manufacturing of a paper web is comparable to a fast additive manufacturing process. However, to build up three-dimensional homogeneous structures with elongated fibres turned up to be quite complicated. The main challenges were fibre distribution and continuously flow during the extrusion process. Then mechanical properties of the substrate and drying of the built structure are critical!
Paper fibres hold together by hydrogen bonding, so water is the primary transporting medium. A recipe of different renewable materials as starch, lecithin, carboxymethylcellulose and other in the paper industry well known chemical additives helped to overcome the first challenges. Finally, the drying process, with its high time consumption and about 20 % dimensional shrinkage effects, still stays unsolved – as long as renewable material shall be used. Using UV hardening agents, the drying problem would be already solved.

photo: Javid Jooshesh

Javid Jooshesh | TU DELFT

Javid Jooshesh born in 1990, is a Phd researcher at the Architectural Engineering + Technology department of architecture faculty in TU Delft. His research is focused on 3D-printing carbon fibre reinforced plastic for ultra-lightweight and high strength building envelope components. Prior to that, he graduated from MSc in Non-standard and Interactive Architecture by Hyperbody and started as a researcher at Hyperbody since 2015 exclusively dealing with the designed engineering of CFRP composites to produce a robotically manufactured, topologically optimised furniture system.

Currently, he concentrates on possibilities of scaling up the potential application of these advanced materials to an architectural application level and deepening the body of work in the domains of digital fabrication, optimisation, and advanced composite behaviour research.

AM for Optimised Fibre-reinforced Ultra-lightweight Facade Elements

The lecture presents the on-going work of investigation through carbon fibre-reinforced plastic composite production via additive manufacturing for developing building facade components with minimum self-weight alongside maximum strength values. Bespoke facade elements will be produced by exploiting the potentials of customised additive manufacturing techniques allowing for calibrated material and structural performance. Whilst the research is in line with the major shift in the design and fabrication paradigms largely known as the 4th industrial revolution, it is deeply rooted in an inter-disciplinary knowledge synthesis between computer science, automation in the construction sector, bio-mimicry and material engineering to produce ultra-lightweight, energy efficient and high strength envelope components.

photo: Jörg Lange

Prof. Jörg Lange | TU DARMSTADT | IFSW

Prof. Dr.-Ing. Jörg Lange, born in 1958, studied engineering at the Technische Universität Darmstadt with the main focus on structural engineering. Afterwards he worked in the technical office of a steel construction company, before he was active in research and teaching from 1985 -1989 as a research assistant at the TU Darmstadt. He finished his doctorate in 1990 on steel-concrete composite construction. He then held various positions in steel construction companies, where he was responsible for the technical realization of steel structures as a project and later as a division manager. He was responsilble for the construction of the Düsseldorfer Stadttor and the 180 m wide aircraft hangar 7 at Hamburg Airport.
Since autumn 1997 he is Professor of Steel Structures at the TU Darmstadt. His research areas include steel in the event of a fire, bolted connections, sandwich elements and AM in steel construction. He is a proof engineer for metal construction, member of various committees at DIN, CEN and DIBt as well as chairman of ECCS TC7 „Cold formed, thin-walled steel in building construction". Jörg Lange is the author of some 200 scientific publications and Ars legend-prize winner 2011.

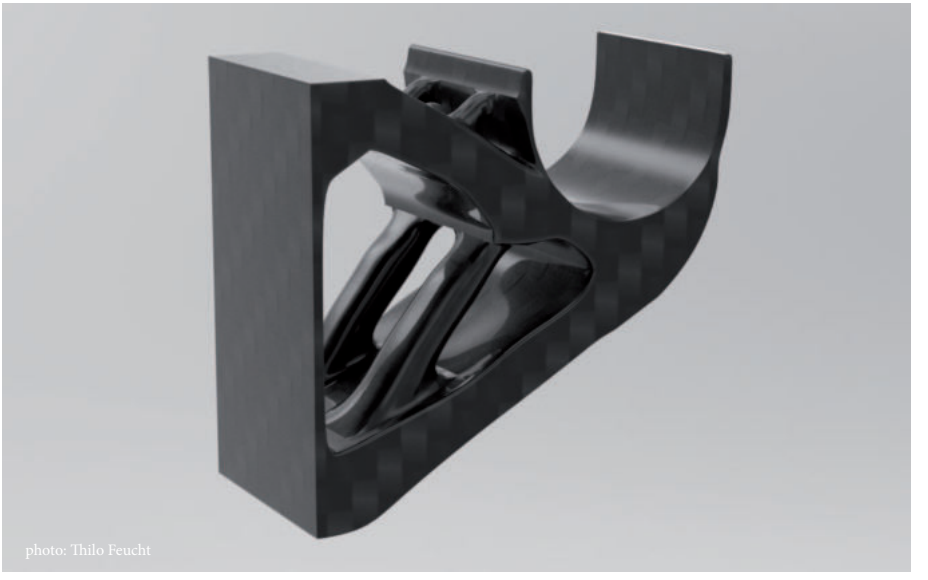


photo: Thilo Feucht

AM in Steel

Structural steel is used for approx. 2 million tons of steel in Germany per year. This offers a great potential for AM. Up to now we concentrate on special solution for exceptional situations. Therefore the presentation addresses three aspects of this large volume market:

- solutions for large lot sizes,
- fabrication, quality control and structural design,
- codes and rules.

Prof. Oliver Tessmann | TU DARMSTADT | DDU

Oliver Tessmann is an architect and professor at the Technische Universität Darmstadt where he is heading the Digital Design Unit (DDU) and a researcher at the Royal Institute of Technology Stockholm. His teaching and research revolves around computational design and digital manufacturing and robotics in architecture. From 2012 – 2015 he has been assistant professor in the School of Architecture of the Royal Institute of Technology (KTH) in Stockholm. From 2008 – 2011 he has been a guest professor at Staedelschule Architecture Class (SAC) and worked with the engineering office Bollinger + Grohmann in Frankfurt.

In 2008 Oliver Tessmann received a doctoral degree at the University of Kassel. He conducted research in the field of „Collaborative Design Procedures for Architects and Engineers“. His work has been published and exhibited in Europe, Asia and the US.

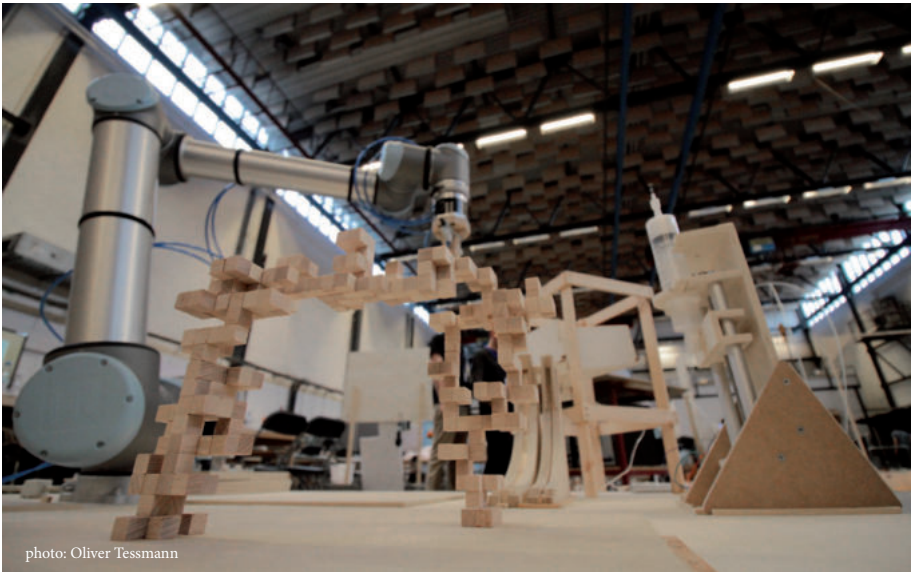


photo: Oliver Tessmann

20.000 Blocks

Anyone can design a building in 20.000 BLOCKS and have it 3D-printed by our industrial robot arm „Ginger". 20.000 BLOCKS is a collaborative platform based on the popular game Minecraft allowing the quick creation and exploration of schematic architectural designs by non-architects. The platform leverages game design to engage participants in a collaborative, creative process.

Most recently, our team used 20.000 BLOCKS to create the IBA_GAME for IBA Heidelberg. In the game you create small neighbourhoods, hundreds of which form a new city quarter in Heidelberg. 20.000 BLOCKS has been published in Wired Germany and featured on the TV channel ARTE. The project has been presented at events and conferences around the world such as SmartGeometry, ACADIA and Perspective Rules, CEBIT and the World Design Symposium in Montreal.

Learn more at www.20000blocks.com and www.20000blocks.wordpress.com

photo: Mattiahs Seel

Matthias Seel | MPA-IFW

Matthias Seel, born 1981, studied civil engineering at the University of the German Armed Forces Munich (UniBwM) until 2007. After working as second company commander and engineer at the German Army until 2009, he was a scientific associate at the professorship "Structural Design and Building Physics" (UniBwM) until 2013. He received his doctor's degree about the calculation of point fixed glasses. Since 2015 he works as a research associate at the Center for Structural Materials (MPA-IfW, TU Darmstadt). His research field is the structural application of glass (AM, strength). Further on, he is a member of DIN working group for „Glass in Building — Design and construction rules".

Robert Akerboom | ISMD

Since March 2017, Robert has been in function at the Technische Universität Darmstadt for both the organization of the glass technology live 2018 event and as a researcher in the field of additive manufacturing with glass. During his Master degree, he added a semester of courses at the University of Melbourne to his program, before deciding to finish his MSc in Delft. For his graduation, he explored the potential of free standing all glass columns assembled from stacked cast elements. After graduation, Robert worked at Bollinger+Grohmann Ingenieure in Paris before switching to the University in Darmstadt, currently combining this with his work as junior engineer for Imagine Structure in Frankfurt.

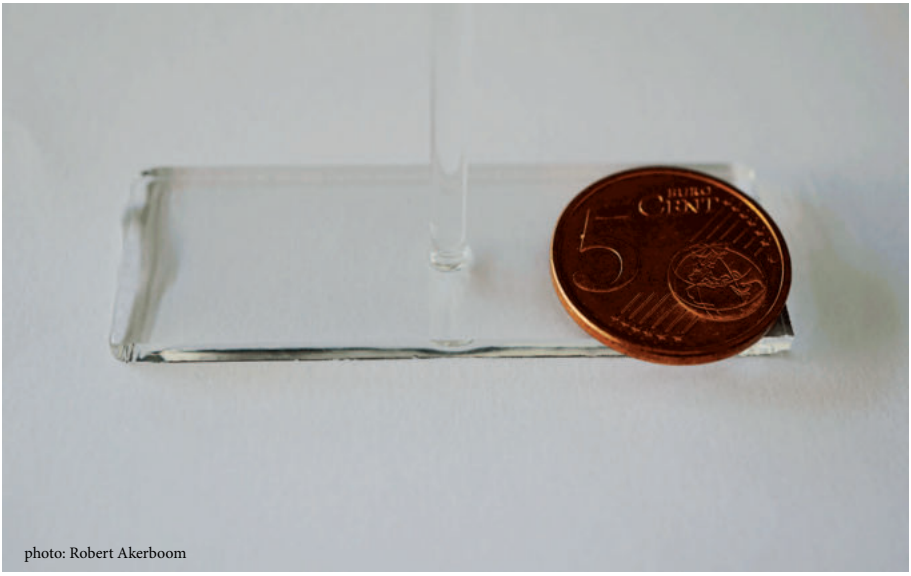


photo: Robert Akerboom

Exploring the Potential of Additive Manufacturing with Glass for Application in the Built Environment

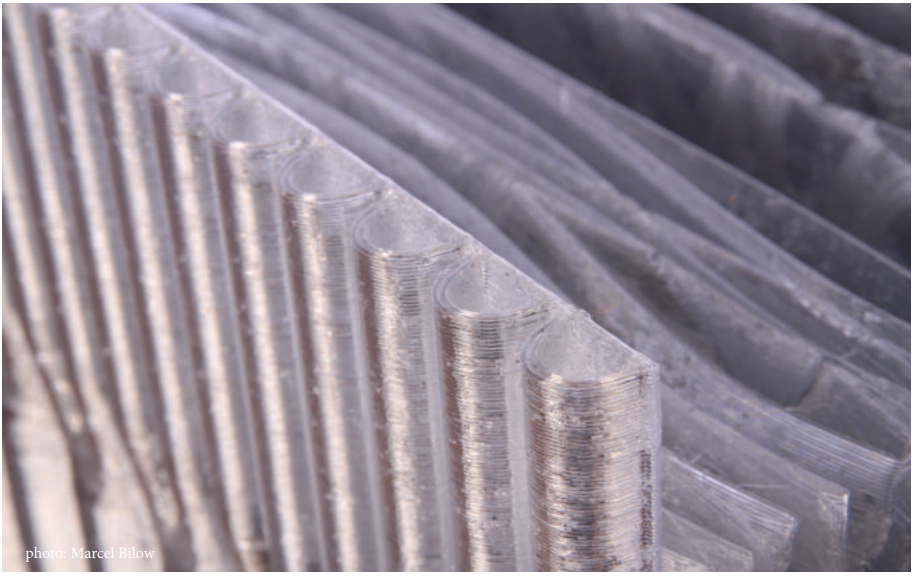
For the built environment and its engineers, glass is an indispensable material with unique properties. The combination of transparency, strength, durability and suitable thermal properties make it an unparalleled and desirable material to work with. There is a potential market for additive manufacturing technologies in the building industry, based on the general production process with a relatively small amount of repetitions of particular building components and the tendency of applying technology innovations for advanced buildings. For this building industry, it seems that AM of glass components holds a lot of potential for joining methods for flat glass structures. Therefore, this paper focusses on the potential of fusing glass filaments on a glass base plate in order to develop scientific grounds to create a machine that can 3D print glass-glass connections for the building industry.

photo: Valentini Sarakinioti

Valentini Sarakinioti | TU DELFT

Valentini Sarakinioti is an architect engineer. She received a Master's degree from Building technology track in the faculty of Architecture and Built environment in TU Delft. Her graduation project focused on 3D printing with plastics, cellular structures and thermal performances for designing a facade component. After her graduation, she worked as a researcher in the chair of Design Informatics in TU Delft. Together with a multidisciplinary team of researchers from TU Delft and TU Eindhoven, she designed a 3D-printed plastic facade system that integrates adaptive heat storage, thermal insulation, and structural performance.

Her focus in research is 3D-printing technology for plastics and the development of an integrated facade component.



SPONG3D: Developing an Integrated 3D-printed Facade for Active Temperature Control in Complex Geometries

AM methods have some advantages over other production processes, such as great freedom of form, shape complexity, scale and material use. In addition, due to inner product part accessibility with additive process, it is possible to integrate multiple design domains to realize complex functionalities. This can provide a potential for façade applications, which is one of the most challenging and complex parts of a building, as it needs to integrate adaptive functions with high thermal performance. The research project SPONG3D aimed at developing a 3D-printed façade panel that integrates insulating properties with heat storage in a complex, monomaterial geometry. The development process was guided by experiments and simulations from multiple disciplines and resulted in the design and manufacturing of a full-scale façade element prototype using FDM printing with PET-G. The project proved the possibility of functions integration in 3D-printed façades, but also highlighted the limitations and the need for further developments.

photo: Michela Turrin

Dr. Michela Turrin | TU DELFT

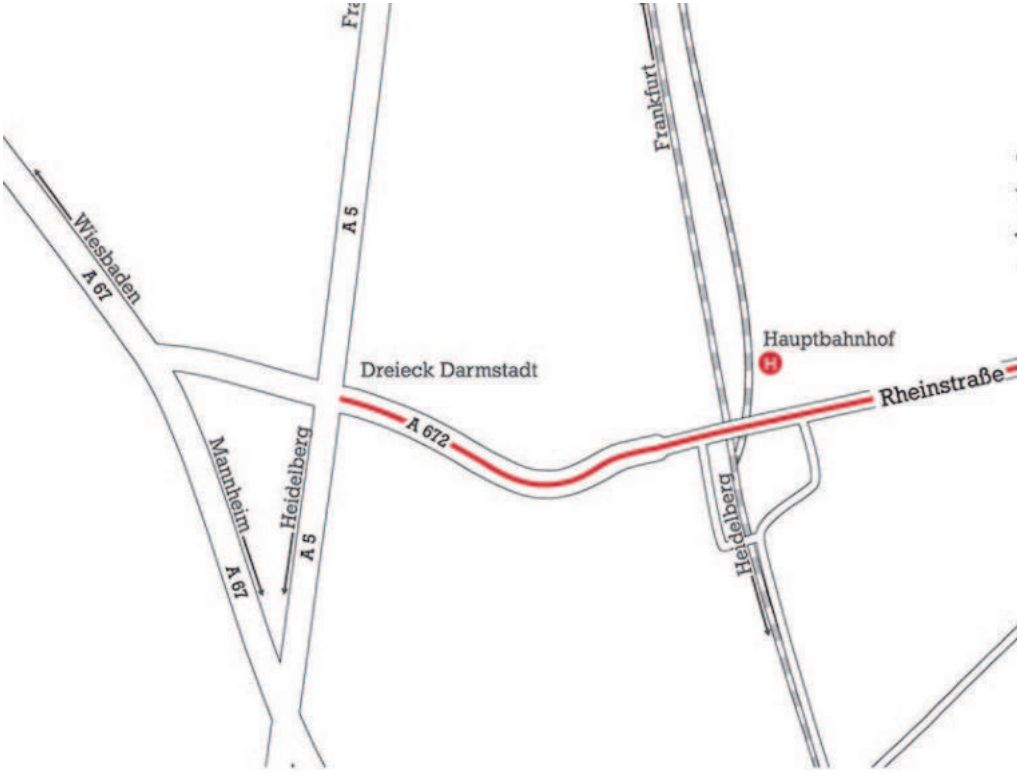
Michela Turrin is an Assistant Professor at Delft University of Technology. Her work focuses on computational design for optimization (to support the exploration of design alternatives) and production (to manufacture complex customized geometries). She leads several granted research projects with practice and industry, with large emphasis on additive manufacturing. She was Marie Curie Fellow at Beijing University of Technology. She worked at Green World Solutions Ltd in Beijing. She taught in international events, among which the IFoU Summer School 2012 in Beijing and Winter School 2013 in Hong Kong. In 2014-2016 she was Excellent Oversea Instructor at South China University of Technology and awarded a grant by the Key State Laboratory of Subtropical Building Science. In 2012-2015 she was senior lecturer at Yasar University in Turkey.

photo: Marcel Bilow

Performative Geometric Complexities

Additive manufacturing allows producing complex shapes in unique items. Complexity in shape is not limited to formal approaches, but opens significant potentials to integrate multiple performances. Moreover, the opportunity to produce items in unique pieces (rather than in series), allows high customization of tailored products. Focusing on the built environment, the lecture suggests new design directions to fine-tune geometries integrating multiple functions and enhancing performances based on highly customized requirements. Several examples are presented, including additive manufacturing for acoustics, for thermal comfort, for structural performances. The geometric complexity of the optimized items is proposed as integral part of their architectural identity, in the attempt of joining highly performing technical solutions with messages of beauty.

Directions

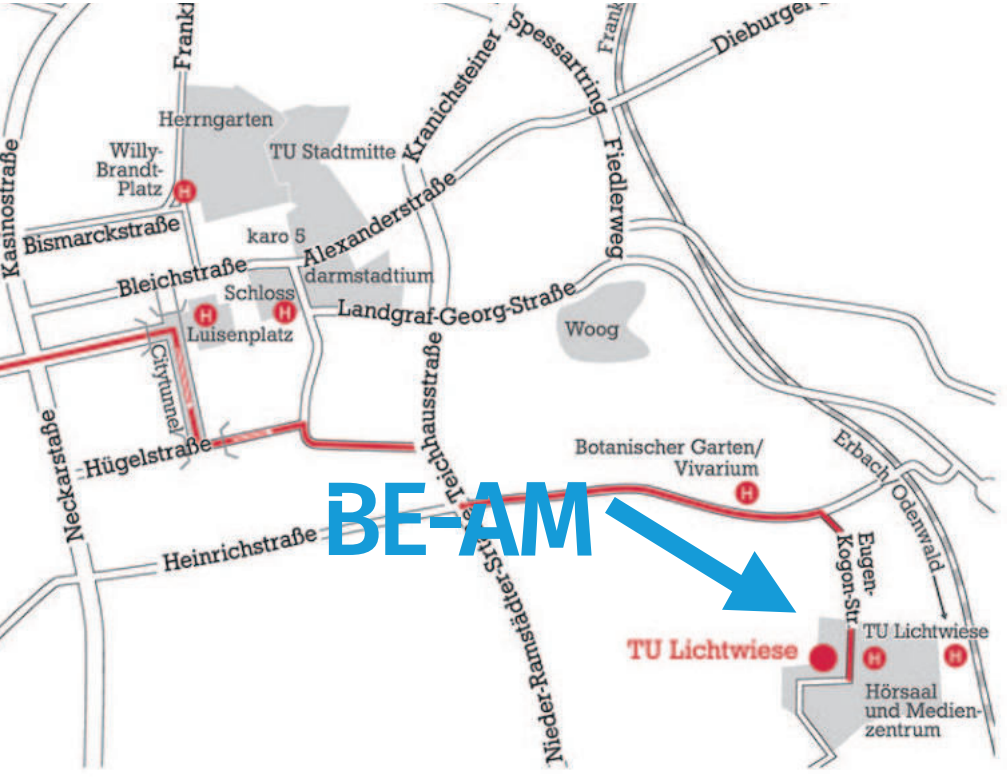


TU Darmstadt
El-Lissitzky-Straße 1
64287 Darmstadt

LECTURE HALL 98
L3|01 Fachbereich Architektur

Taxi
Under the telephone number 06151 19410 you reach the Taxifunk Darmstadt.

Access by car
You can park your car in the designated parking area at a daily rate of 2.50 €.

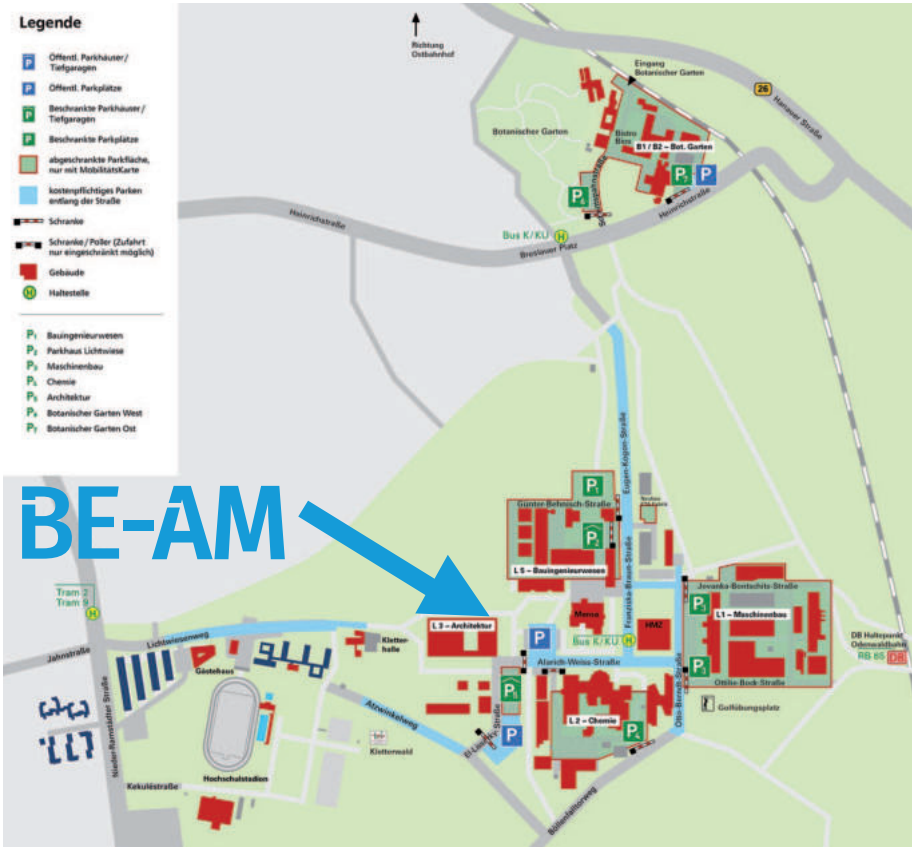


Access by public transport
The TU-Lichtwiese campus can be reached by public transport via the bus stop TU Lichtwiese / Mensa and via the railway station of the Odenwaldbahn (VIAS) Darmstadt TU-Lichtwiese Bahnhof.

From Darmstadt main station
Take the bus line K in the direction of TU Lichwtiese to the stop „TU Lichtwiese / Mensa". The journey takes about 18 minutes.

From Frankfurt main station
From Frankfurt main station, the R65 (Odenwaldbahn) is also a direct connection to the railway station Darmstadt TU-Lichtwiese. The journey time is about 40 minutes, every 2 hours.

Parking



Car Parking Availability

You can park your car in the designated parking area at a daily rate of 2.50 €. Please note that only the blue parking facilities are accessible to the general public. Along the Eugen-Kogon-Straße, the Franziska-Braun-Straße and the Alarich-Weiss-Straße you have the possibility to park your vehicle along the street.

Contact

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