

Forschungsschwerpunkte – Prof. Achim Menges

Humans spend 87 per cent of their lives in buildings. Architecture is the habitat of mankind. Therefore, it is of central ecological, economic, social and cultural relevance. This generates significant challenges: By 2050, 2.6 billion people will require new housing, workplaces and infrastructure due to rapid urbanisation and population growth. For example, in Germany alone, 400 000 new residential units and related commercial and public buildings need to be constructed every year, but only half of this demand can currently be met. The productivity of the building sector has been stagnating since the 1990s, and it has struggled to complete major buildings in time and on budget. Moreover, already in its present state, the building industry is responsible for approximately 38 per cent of global CO₂ emissions, 40 per cent of energy and resource consumption, and 50 per cent of global waste. It is evident that mere incremental improvements to established approaches to design and construction will not be able to meet these severe challenges. Instead, new approaches are urgently required.

Digital technologies make it possible to address these challenges and opportunities in novel ways. However, their adoption is slow in the building industry, and typically only focused on isolated aspects of the building process due to a compartmentalised research culture and the fragmented nature of the construction sector. Achim Menges' research aims to harness the full potential of digital technologies in order to rethink design and construction. His work strives to contribute to laying the methodological foundations for advancing architecture based on an integrative computational approach, which concurrently addresses design and engineering methods, fabrication and construction processes, and material and building systems. It encompasses interdisciplinary research with structural engineering, building physics, manufacturing and systems engineering, computer science and robotics, as well as the humanities and social sciences.

Achim Menges' research primarily focuses on timber architecture and fibrous architecture. In the timber research area, the work aims to explore, establish and explain meaningful and novel relationships in the field of computational wood architecture and robotic timber construction. Based on an interdisciplinary research approach and the pro-active engagement of multi-faceted stakeholders across industry and society, the work seeks to develop computational design and digital fabrication methods and related next-generation wood building systems,

with the goal of contributing to the development of resource efficient, spatially attractive, ecologically sound and future-proof timber architecture.

The research area focused on fibrous architecture investigates novel methods and processes related to the design, engineering and fabrication of large-scale fibre composite structures aiming for a new kind of genuinely digital building systems. One particular focus is a novel process called coreless filament winding, which is based on the process of formation of free-spanning fibres without relying on a mould. It significantly reduces material expenditure through load-adapted fibre arrangements and covers a wide range of material systems, from carbon and glass fibre composites to experimental natural fibres and bio resins.

In the research area of human machine collaboration in architectural design and building construction, Achim Menges' work explores novel concepts for task sharing between human and machine actors in semi-autonomous fabrication setups. It uses immersive technologies for human skillset extension, information transfer and fabrication control, which fundamentally changes the conceptual approach to the prefabrication of building components.

In addition, he also investigates fully autonomous construction processes such as distributed robotics, which is an emerging field of research interested in the assembly, disassembly, rearrangement, and maintenance of architectural structures using large teams of small, agile mobile robots. This represents a fundamentally different approach to current construction automation and has further implications on the entire lifecycle of buildings. As such, the distributed robotics research is investigating the potentials of and fundamental methods for deploying inexpensive machines for the production of complex, functionally adapted structures in highly parallel processes.

Beyond the programming of machines, the concept of material programming denotes a method of design in which advanced functions are encoded directly within physical fabrication logics and syntax material systems, in place of mechatronic systems with digital controls, sensors and actuators. With a specific focus on the utilisation of natural and bio-based materials, Achim Menges' research on architectural material programming is investigated through simulation and computational fabrication, with the aim to develop novel methods of form generation, such as construction-scale self-shaping manufacturing, and form adaptation, for example for adaptive building systems such as weather-responsive building skins.

Many of the aforementioned aspects of architecture, from design to fabrication, construction and operation, can be conceived of as complex social and/or technical systems. Such systems consist of multiple interacting entities, people, objects, or both, that are embedded in an environment, with which they also interact. Complex systems are characterised by non-linear behaviour often expressed as emergence or self-organisation. Achim Menges' work in the research area of agent-based modelling focuses on modelling and understanding complex systems in architecture in order to harness their complexity for the design of the built environment.

Overall, Achim Menges' research strives to make methodological contributions to a liveable and sustainable future built environment, high-quality yet affordable architecture and a novel digital building culture.