Facade 2018 -

adaptive!

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Proceedings of the COST Action TU1403 – Adaptive Facades Network Final Conference:

Facade 2018 - Adaptive!

This book is based upon work from COST Action TU 1403 adaptive facade network, supported by COST (European Cooperation in Science and Technology).

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Cover image
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Layout
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Publisher
TU Delft Open

Proceedings of the COST Action TU1403

Adaptive Facades Network Final Conference

Facade 2018 - Adaptive!

Lucerne University of Applied Sciences and Arts
Lucerne, Switzerland
26-27 November 2018

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Preface

Lucerne University of Applied Science and Arts, the European Façade Network and the European research network COST Action TU1403 “Adaptive Facades Network” have joined forces in the organisation of the FAÇADE 2018 – Adaptive! Conference. This international scientific conference - held on November 26-27, 2018 at the culture and convention centre Lucerne (KKL), Switzerland – focuses on adaptive, multifunctional and dynamic building envelopes. It gathers excellent architects, engineers, researchers and representatives from the façade industry to discuss recent façade projects, the advances in the design, new adaptive technologies and future developments in research.

Within the FAÇADE conference series, this is the fifth edition – following the editions in 2010, 2012, 2014 and 2016 - held in Lucerne and organized by Lucerne University of Applied Science and Arts. Within the COST Action TU1403, it follows the mid-term conference held at the TU Munich in 2017. This book provides the proceedings of the FAÇADE 2018 – Adaptive! Conference and, as such, it forms one of the final publications of the COST Action TU1403 with the booklets ‘3.1. Cases Studies’, ‘3.2 Performance Simulation and Characterisation of Adaptive Facades’, ‘3.3. Research and Education’, and the Special Edition Adaptive! of the Journal of Façade Design and Engineering (JFDE), which is dedicated to the conference FAÇADE 2018.

Nearly 60 peer-reviewed papers, published by more than 150 authors from 30 different countries, provide a profound state-of-the-art on adaptive facades. Thirteen high quality papers have been selected by the scientific committee to be published in the special edition of the JFDE journal.

The papers are divided over five subthemes, which address products and materials for adaptive facades, strategies for design, performance assessment, experimental tests and post occupancy evaluation of adaptive facades. Moreover, five keynote presentations provide inspiring projects and ideas for further reflection.

Organising this conference and editing the conference proceedings has once again been an enjoyable experience. We would like to acknowledge all authors for their contributions, the scientific committee members for their valuable comments, our esteemed keynote speakers for their inspiring presentations, and of course, all conference participants for their interest in this event. In addition, we are grateful to our Sponsors Stahlbau Pichler, MHZ and HALIO, as well as the non-profit organisations Suisse Innovation Agency (Innosuisse) and the Swiss association for windows and facades (SZFF) for supporting the organisation of this conference. We also would like to thank the editors in chief of the JFDE journal, Ulrich Knaack, Tillmann Klein, Thaleia Konstantinou and Alejandro Prieto for their great support and the special edition dedicated to the FAÇADE 2018 – Adaptive! conference.

Finally, we would like to acknowledge COST for supporting both the conference and publication of these conference proceedings, and all COST Action TU1403 members for their contributions to make this happen. Particularly we would like to thank science officer, Mickael Pero, and administrative officer, Carmencita Malimban, for their great and valuable support during the course of COST Action TU1403.

We wish you an enjoyable conference and we hope you will find inspiring publications in these proceedings.

Andreas Luible, Susanne Gosztonyi & Stephanie Ly-Ky
Conference Organisers

Andreas Luible, Mauro Overend, Laura Aelenei, Aleksandra Krstic-Furundzic, Marco Perino, Francesco Goia, Frank Wellershoff, Shady Attia, Ulrich Knaack, Uta Pottgiesser, Christian Louter
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Adaptive Façades and Topology Optimization

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The study examines the main possible approaches for a generative use of topology optimization aimed at the study of the conditions of "adaptability" of façades in architecture. The analysis regards the possibilities of technological transfer of topology optimization methods and strategies to the conception of framing and enclosure components of building envelopes, through the explanation of some experiments and applications. The topology optimization is analyzed and supported as the possible area within which it should be possible to sustain new forms of calibration of material densities, of morpho-typological sizes and structural performances with the least material used and energy wasted.

Keywords: Topology optimization; Technological transfer; Modelling and executive design; Additive manufacturing; Lattice and cellular structures.

1 Introduction

The thematic proposal deals with the contents and experimental procedures of development aimed at topology optimization with the aim of defining some methodological approaches and strategies for the conception, the design and the construction of building envelope systems, components and connective interfaces within the frame of the advanced contemporary architectural scenario. The study aspires to a possible contribution to the technological transfer of some planning, managing and solving issues, by laying down criteria relating to "digital/virtual design" procedures (Zheliazkova, Naboni, Paoletti 2015), "productive/constructive customization" technics (Paoletti 2013) and "executive design" methods (Nastri 2009; 2017), relating to the scope of the adaptive façades. According to this study, the adaptive character concerns the design, productive and constructive methodology, which is able to make the structural and envelope components of building envelope systems adjustable, in respect of specific parameters regarding:

- The mechanical loads expected and established during operating conditions;
- The needs of connection between supporting elements and connectors;
- The specific characteristics of framing materials and building envelope and cladding systems.

The study examines the "adaptive" character of the described systems as a model that should lead to a research in order to define a methodology able to be:

- Used in different types of frames, junction devices and their respective materials;
- Flexible and adaptable to specific design needs.

The scientific contribution of this research consists in the analysis of certain applications concerning topology optimization, in order to identify a possible approach for study and development, both methodological and procedural, in order to deal with particular needs regarding morpho-typological, expressive, functional, productive and constructive aspects for a new approach to building envelope and cladding systems design within advanced architecture. Furthermore, this research aims to

bring out the potential of topology optimization in order to identify possible developments within the productive environment up to:

- The specific conception of systems, technical elements, technical interfaces and junction devices;
- The design (not only bi-dimensional, but three-dimensional as well) of building enclosure and cladding systems according to a variable, flexible and innovative configuration of building curtains.

In this respect, the study focuses on the characters of topology optimization in order to define some possible actions to develop building envelope systems, components and connective interfaces (in the field of Industrial Mass Customization) through:

- The adoption of techniques making it possible to synthesize the formal determination that from a given volume will produce both productive and constructive innovation and customization processes;
- The methodology aimed at shaping the geometric, structural, and physical constitution according to the expected performance, in terms of mechanical strength and material distribution considering the lowest weight, with regard to feasibility constraints and in conjunction with automotive manufacturing practices, which can provide mass production of customized solutions;
- The practice of “interoperability” between structural, thermal and/or environmental modeling, aimed at predicting the performance assessment of technical systems.

The object of dealing with the topology optimization regards the development of methodological approaches directed to the “adaptability” of the building envelopes proposed to :

- The interaction between the conceptual references supporting “manipulation” and “exploration of phenomenal reality” activities and cognitive and operational procedures based on digitalization and virtual composition (morpho-typological, performance oriented, physical and aggregative) processes and tools;
- The implementation of cognitive and operational “models” aimed at the simultaneous cognitive acquisition (through predicting and anticipation aspects), assessment and executive simulation of the project;
- The strategies of “artificial reproduction”, in order to predict and control the “operational modes” using “modeling representation” (through “predictive/executive models”, aimed both at “indirect” observation and at analytical and operational formulation; Naboni and Paoletti 2015).

The thematic proposal, which implies the theoretical references gained from a series of projects, researches and experiments considering reality of production and construction as something “manipulable” and “calculable”, aiming for the next step of “empirical education” and “executive materialization” of data, is expressed through the strategies directed to the morpho-typological, geometric, structural and connective “calibration” of the building envelopes (as an intended form of “adaptability” according to the shape-size-structural optimization activities; Paoletti 2017). Therefore, the technological design culture of topology optimization processes is further explored and proposed to the “adaptive” conception of the building envelopes, according to:

- The activity based on principles acquired in industries that extensively use digital technologies (i.e. the automotive, aerospace and biomedical industries), in order to manage in a coordinated manner the design, production and construction stages of composition, systemic and connective solutions;

- The simulation and predicting anticipation methods of design solutions in order to assess procedures and economic aspects, “optimize” production lines (reducing the amount of material employed, viewed from the viewpoint of the effective functional needs), thus reducing polluting emissions and the use of energy supply;
- The qualification, certification and standardization prospects of management, design, production and construction processes within the AEC industry (Architecture, Engineering and Construction Industry), in order to identify possible references and avenues for a normative formulation concerning innovative products.

The study is developed through a series of contents organized according to the analytical articulation of the main themes regarding the possibility to apply some topology optimization methods and strategies to the “adaptability” of the design of building façades (1) and the in-depth treatment of some examples regarding the design of the building envelope joints (1.1) and of the reinforced concrete sections and “shells” (1.2). Thereafter, the study focuses on the topology optimization and the design through the periodic base cells (2) and through the lattice structure (3) as a strategy for the “adaptability” of the building envelopes to the morpho-typological and mechanical needs: in particular, this theme regards the development and the possible technological transfer of the lattice structures and cellular materials (3.1), the lattice micro-structured architecture (3.2), the material system of additive manufactured lattice structures (3.3) and the research on lattice cell typologies (3.4). Moreover, the study examines the topology optimization through modular systems and opens to the multi-objective optimization and “adaptability” of the building envelopes (4).

2 Topology optimization: strategies and methods for the possible technological transfer to the “adaptability” of building envelopes

The study is based on the cultural and scientific field related to the development of the design methods aimed at the generation of new forms in architecture, where performances are integrated not merely into an evaluative discourse, but as generative “parameters”. Within this context:

- The topology optimization process has emerged as a scientific approach to evaluate form and structure jointly (on the basis of aerospace and automotive industry, where the optimization of mechanical parts is performed in connection with an efficient material usage);
- Topology optimization should be directed to the study of the building envelopes as a new approach for the morphogenesis and for the calibration of structural elements, considering the potential of creating shapes that can complement and inspire the generation of architecture.

The study of the technology transfer and of the application of the “adaptive” strategies to the building envelopes contemplates:

- The developing load-bearing systems that economically satisfy the design performance objectives and safety constraints;
- The minimization of resource consumption that refers to the selection of the best element from some sets of available alternatives (Radman 2013);
- The purpose of the topology optimization as an approach focused on shaping in order to find the optimal thickness distribution (e.g. the optimal member areas in a truss structure). The optimal thickness distribution that minimizes (or maximizes) a physical quantity such as the external work, the peak stress and deflection, while equilibrium and other constraints on the state and design variables are satisfied;

- The approach focused on sizing, according to the development of the design model as a fixed parameter throughout the optimization process;
- The determination of features such as the number and location and shape of holes and the connectivity of the domain (Bendsoe and Sigmund 2003).

In this way, the contribution to the design methods related to the “adaptability” of the building envelopes pertaining to the specific requirements and conditions regards the aim to optimize the structural contents by finding ideal topology configurations that suggests a layout of framing and enclosure elements and, eventually, a specific material distribution given by specific design conditions. The topology optimization processes transferred to the context of structural needs and problems of the building envelopes constitutes an approach that optimizes material layout within a given design space, for a given set of loads and boundary conditions such that the resulting layout meets a prescribed set of performance targets (Radman 2013). Moreover, the responses of structural systems to the external loading conditions are highly dependent on the material they are built from.

On this basis, the strategies for the topology optimization aimed at the “adaptive” design procedures of the building envelopes are intended as an aid to generate architectural structures, framings and components, so that the output of the process should be strictly morphogenetic and suggest actual forms in relation to a defined spatial boundary and requires the needed integration of the structural problem with the architectural one. According to this proposal, therefore, the topology optimization aimed at the composition of the building envelopes should consider:

- The definition of the boundary conditions, such as the applied external loads, the support conditions, the volume of the bounding box including the structure and, eventually, some additional design restrictions such as the location and size of prescribed holes or solid areas;
- The determination of the optimal organization of a specific material in space most often according to structural compliance or stiffness (Figure 1).

Fig. 1 Strategies for topology optimization directed to the building envelopes to generate architectural structures and components.

2.1. The topology optimization approach to the “adaptability” of the building envelopes joints

The study supports the technological transfer of the topology optimization directed to the “adaptability” of the design conditions of the building envelopes through the development of structural connections, as exemplified by the technique to realize the 3D printing steel joints.

In order to point out the possible contribution to the design of the framings and of the technical interfaces, the analysis considers the results achieved through a project by Arup Engineering in collaboration with WithinLab, CRDM/3D Systems, expert in additive manufacturing, and EOS; Paoletti 2017). In particular, the study examines the pioneering proposal by Arup Engineering that represents a solution for steel nodes in lightweight envelopes characterized by complex shapes and customized design: the shaped elements are optimized by SIMP method and topology optimization results in an organic form using less material while the original functions are still ensured (Block et al. 2015). Compared to traditional design, the technological transfer opportunity suggested to the “adaptive” conditions of the building envelopes joints should regard:

- The approach capable of providing the calibration of material and causing an increase of the node stiffness;
- The process based on the principle of the additive laser sintering, employing the steel derivatives as the printing material. The structural nodes have been originally conceived in stainless steel and later produced with steel, compatible with the technology of the machine (owned by the partner CRDM). This material is about four times stronger than a normal construction steel, which made Arup Engineering eager to experiment with it and further explore its potentials;
- The additive manufacturing that report how this technological solution guarantees a 40% reduction of CO2 emissions over the whole lifecycle compared to the traditional casting processes;
- The process of the direct metal laser sintering (DMSL) satisfies many design requirements, reducing weight and preserving geometrical freedom. Due to the nature of additive manufacturing techniques, the production of waste materials is minimized and the weight of the final product reduced by 30% (Figure 2).

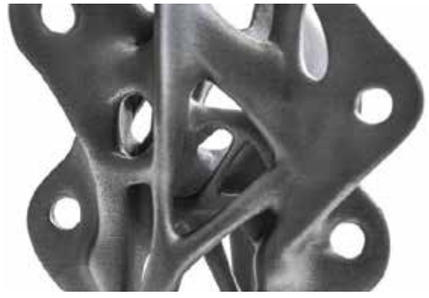

Fig. 2 3D printed structurally optimized steel joints “adaptable” to the design process of the building envelope joints (credits: Arup)

2.2. The topology optimization approach to the “adaptability” of the building envelope sections

The study supports the technological transfer of the topology optimization aimed at the “adaptability” of the design conditions of the building envelope sections, as exemplified by the application to the reinforced concrete sections, through an integral approach in which the generative design was essentially supported by a fabrication setup of robotic CNC-milling of EPS moulds (as the result of an interdisciplinary project led by the Aarhus School of Architecture; 2007). To prove this approach, a concrete structure (which required the use of self-compacting concrete and of steel reinforcements) was designed and built in the form of an asymmetrical, doubly curved slab structure, where the shape resulting from the topology optimization was then re-modelled and used as negative form to generate the EPS mould forms to be cut. According to this experiment, which finally ended up with the construction of a full-scale prototype (with a complex shape

that would be difficult to manufacture with typical methods), the study intends emphasizing the possibilities of forming an “adaptive” strategy for the building envelope sections through:

- The emergent structural design that provides a new tectonic language where the natural load path is immediately visible;
- The construction realized with high precision and ease of mould production (with the use of the robot CNC milling);
- The reduction of material consumption up to 70% in comparison with massive equivalent structures subjected to loading conditions and requirements by international standards (Figure 3).

Fig. 3 The topology optimization directed to the building envelope sections according to the application of the reinforced concrete, supported by a fabrication setup of robotic CNC-milling of EPS moulds.

3 Topology optimization and design through the periodic base cells aimed at the development of the building envelopes

The study examines and supports the topology optimization directed to the building envelopes regarding the methodological approach to “adapt” the material organization at the micro-scale: this strategy is experimentally extended to the Periodic Base Cell (PBC) that represents a heterogeneous continuum structure comprised of different constituent materials or phases (Bendsøe and Sigmund 2003). The topology of the PBC is what influences the properties of materials; hence the major challenge in the design of these materials would be the determination of the optimal spatial distribution of the constituent materials within the PBC. In the simplest form, the periodic composite materials consist in a 2D or 3D scaffold of matrix, in which the other phases are included: therefore, it is reasonable to apply the structural topology optimization methodologies for the determination of the spatial distribution of the phases (Radman 2013). According to these applications, the study means to support the “adaptive” conditions of the building envelopes considering that:

- The materials with repeating or periodic microstructures usually consist of one constituent phase and a void phase (known as porous or cellular materials), or combinations of two or more different constituent phases with or without the void phase (also named “periodic composites”);

- The overall properties of these types of materials are controlled by the spatial distribution of the constituent phases within the PBC, as well as the properties of the constituent phases;
- The periodic composites, in comparison with traditional composites, demonstrate greater flexibility in terms of their capability to be tailored for prescribed physical properties, by controlling the compositions and/or the microstructural topology of the constituent phases. They can also be easily tailored to have gradation in their functional properties, in the form of a Functionally Graded Material (FGM) through gradual changes in the microstructural topologies (Figure 4).

Fig. 4 The topology optimization directed to the building envelopes according to the optimal spatial distribution of the constituent materials within the Periodic Base Cell (PBC).

4 Topology optimization and design through the lattice structure directed to the development of the building envelopes

4.1. Topology optimization of the lattice structures and cellular materials directed to the development of the building envelopes

The study examines and supports the topology optimization approach by considering the “adaptability” of the building envelopes in respect of the lightweight of framing and sections, through the analysis and the application of cellular materials, which might be characterized by advanced physical, mechanical and thermal properties that extend far beyond those of solid materials. According to this approach, the “adaptability” of the building envelope should be analyzed in relation to the physical characteristics of the materials that can vary by changing the distribution within their microstructure: in order to make the best use of the resources, the spatial distribution of the constituent phases within the microstructures can be defined by using topology optimization techniques. These types of cellular solids should be transferred and used for the building envelopes due to their high structural stiffness, high strength-to-weight ratio, low energy absorption, good thermal conductivity, and acoustic insulation; although the structural weight is not generally a functional property, it might happen to be one of the important design factors. In particular, the study intends to support the “adaptive” conditions of the building envelopes considering that:

- The material is composed of Periodic Base Cell (PBC), which is the smallest repeating unit of the structures;
- The dimensions of the base cells are assumed to be much less than the overall length scales of the material body, and at the same time much larger than the atomic length scale;

- The PBC's are discretized into a finite elements model under periodic boundary conditions, where the finite element analysis is performed to extract necessary information for the calculation of the effects of individual elements (within the PBC) on the variation of homogenized (average) properties of material: this through the appropriate distribution of the solid phase within the PBC, subject to a prescribed volume fraction of the solid phase (Radman 2013) (Figure 5).

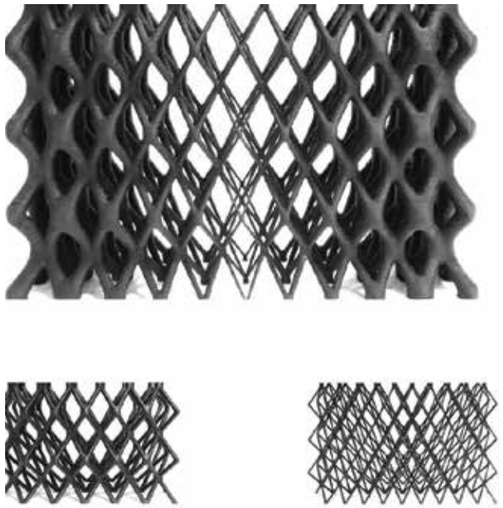

Fig. 5 Topology optimization directed to the building envelopes considers the study of the lightweight cellular materials (credits ACTLAB, Politecnico di Milano)

4.2. Topology optimization of the lattice micro-structured architecture for the concept design of building envelopes

The study examines and supports the topology optimization approach considering the "adaptability" of the building envelopes in respect of the technological transfer and application of a specific type of cellular solids, identified as the lattice microstructure. The potential of this system relies on its implicit resistance and reduced use of material, combined with the possibility to be "adapted" to a large variety of façade shapes. The study observes, for possible application to the building envelopes, the lattice microstructures both as a structure and as a material, consisting in an interconnected network of struts, pin-jointed or rigidly bonded at their connections. At one level, they can be analyzed using classical methods of mechanics, as typical space frames; on the other side, within a certain scale range, lattice can be considered as a material, with its own set of effective properties, allowing direct comparison with homogeneous materials: in particular, the mechanical properties of lattice materials are governed, in part, by those of the material from which they are made, but most importantly by the topology and the relative density of the cellular structure.

The study contemplates that applications of the lattice structures in construction, for possible use in "adaptability" of materials and structures of the building envelopes, are developed in connection with new fabrication methods, involving additive manufacturing and industrial robotic arms, often based on polymer pultrusion in space to create façade reinforcements (Hack et al. 2015): these are based on the use of fiber-reinforced composites to produce modular struts, assembled by

robots (Cheung 2012) and based on the employment of additive manufacturing to produce sand mold halves casted with Ultra High Performance Concrete (UHPC) for the realization of three-dimensional spatial lattices (Morel and Schwartz 2015). The topology optimization strategies, considered in terms of the "adaptable" physical constitution of the building envelope enclosures, are intended and supported as an early-stage design tool to give the designer an insight into an efficient and continuous lattice microstructure layout. In particular, the study means to support the "adaptive" conditions of building envelopes considering that:

- Topology optimization is fed with two-dimensional free-form shapes, which represent a possible "draft" of the building envelope configurations to be evaluated, along with a description of the specific boundary conditions such as loads, constraints and material properties (Bendsøe and Sigmund 2003);
- The representation directed to the building envelope configurations should be converted into a Functionally Graded Lattice structure, where the mechanical behaviour provides the needed information to evolve a polyhedron into highly specific cells with locally optimized cell dimensions and orientation, struts diameter and section as well as material characteristics (Figure 6).

Fig. 6 3D base cells, 2 x 2 x 2 cells and effective elasticity matrices of 3D cellular materials with maximum shear modulus; volume fraction is (from top): 45% ; 35% ; 25% ; 15% (Radman 2013).

4.3. The material system of additive manufactured lattice structures for the concept design of building envelopes

The study looks at how, within the field of the "adaptive" characters of the building envelopes, the shift from prototyping to direct manufacturing is mainly connected to material improvement, which in comparison with product design is more complicated to achieve: material characteristics and behaviour, mechanical properties and dimensional requirements are key elements in evaluating the use of additive manufacturing for large scale applications (Naboni and Paoletti 2018). Therefore, the exploration of a material system should be carried out in order to understand the way it can

be exploited, with a rigorous multi-scalar analysis of the material coupled with the fabrication system that will be used. This process starts with analyzing the materialization process through the fabrication experiments and the observation of their geometrical and mechanical characteristics. As result, a set of specific boundary conditions for the fabrication systems, involving mechanical, software and material interdependencies, is defined. Within the frame of this research, use is made of a delta-robot, a typology of printer intrinsically agile that guarantees an ideal travel speed for the production of discontinuous geometries such as the lattice structures.

In particular, according to the technological transfer to the “adaptive” characters of the building envelopes, the employed material, experimented and indicated, should be the High Performance PLA (Polylactic Acid), a polymer with discrete mechanical properties that are leveraged by its superior printability. An extensive campaign of the fabrication tests has been conducted with it to define print settings in relation to geometric constraints, printing time, printing resolution and mechanical resistance of the lattice microstructure. Among various aspects, an important one emerged as the necessity of evaluating models to be printed according to the geometry limitations in overhanging angles, to avoid the need for support geometries with resultant t inefficiency in the use of material. The relation between the deviation angle from the vertical axis and the number and thickness of shell elements is fundamentally driving the resolution and refinement of the production (Figure 7).

Fig. 7 The material system of additive manufactured lattice structures based on the multi-scalar analysis of the material coupled with the fabrication system (credits ACTLAB, Politecnico di Milano)

4.4. The research on lattice cell typologies directed to the building envelopes

The study, focused on the architecture of the lattice structure directed to the “adaptable” development of the micro-structure of the building envelopes, proposes to analyze:

- The definition of the base unit cell, which implies that the above-mentioned geometry constraints of FDM are to be taken into account first in this evaluation;
- The conduction of the comparative multi-criteria analysis of typical three-dimensional cells, with an evaluation of printability, relative density and visual permeability (considering different typologies as orthogonal grid, star, tesseract, octahedron, cross, octet, ventiles and diamond);

- The evaluation of the overhanging angles and of the visual permeability, which is measured in relation to the projection of the unit cells on a vertical plane (using a 30° angle of view) (Figure 8).

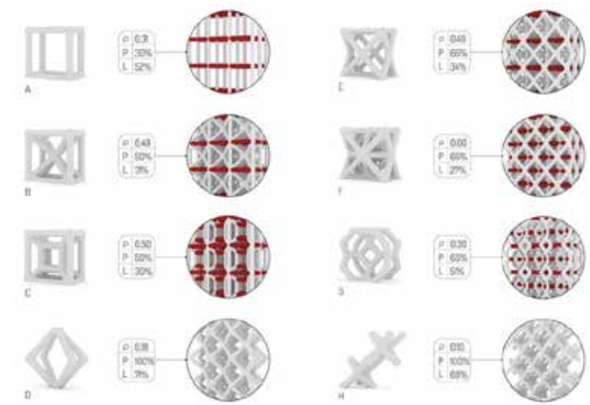

Fig. 8 The image shows eight different unit cell typologies for the Cellular Lattice Structure and their observed characteristics; first column shows unit cell types: A - orthogonal grid, B - star, C - tesseract, D - octahedron, E - cross, F - octet, G - ventiles and H - diamond; second column shows the relative density (ρ), printability (P) and light permeability (L); third column shows the repeated unit cell in a skin system, highlighting in red elements that are not possible to be fabricated with FDM. (credits: ACTLAB, Politecnico di Milano)

5 Topology optimization of the building envelopes through modular systems

The topology optimization strategies are studied for the application to the building envelopes through use of modular systems, intended as “open” and “adaptive”, such as the STRUNA (word born from the crasis of “STRUcture” and “NAture”) which shows the contemporary opportunities of computational design techniques combined with advanced manufacturing systems. The methodological approach is directed to the concept of “adaptive” modular building envelopes, capable of combining and accommodating “adaptable” structures, which conforms to the space. The STRUNA system (developed at the Politecnico di Milano, in collaboration with the Faculty of Agraria of the Milan State University) recalls the names of the modular pieces of furniture of the famous Swedish brand, but it surpasses its Fordist logic to become a mass-customizable system, lively and flexible. Accordingly, structure and envelope components joined in a system that is dynamic, self-bearing and can be configured as a filter between exteriors, interiors and between spaces. In line with the most advanced trends in high yield crop cultivation with the least ecologic footprint, the STRUNA system is also “adaptable” - besides traditional and hydroponic cultivation methods - for the cultivation of micro-algae, whose photosynthesis is made possible not only by the sunlight, but also by a low consumption LED system, ensuring non-seasonal yield (Figure 9a, b, c).

a) b) c)

Fig. 9a), b) and c) The STRUNA structure developed as a result of computational design techniques combined with advanced manufacturing systems. (credits: SAPERLab, ABCLaboratorio, Politecnico di Milano)

6 Conclusion

The study, attempting to categorize the use of topology optimization (experimented in different areas), aims to support the technological transfer and the methodological approach to the conception of new morphogenesis, production and construction strategies for the structural framings and enclosures of building envelopes, observing:

- The topology optimization process that is analyzed as a possible technique to achieve the characters of “adaptability” to façades while creating efficient physical, material and structural organization;
- The integration of additive manufacturing methods that have introduced innovative materialization processes, where logics of sustainability and efficiency (typical of mass-production) are no longer applicable: taking inspiration from the remodeling process of bones, a design methodology based on topology optimization that “adapts” to different shapes and loading conditions is developed;
- The experimental approach finalized to complex shapes neither pre-optimized by shape, nor post-rationalized to meet manufacturing constraints, supporting the manufacturing process with increased chemical, mechanical and weather resistance.

This promising research ambit can widen designers competences and capacity to inform their design with performances from the very beginning of the design phase.

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ISBN 978-94-6366-102-7

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IN SCIENCE AND TECHNOLOGY

COST is supported by the EU Framework Programme Horizon 2020

COST TU1403
fn Adaptive facades network