Lapella Chair

Stereotomy 2.0's experiments on fibre-reinforced stone

Maurizio Barberio Politecnico di Bari, Dipartimento DICAR *mb@newfundamentals.it*
Shajay Bhooshan Zaha Hadid Architects *shajay.bhooshan@zaha-hadid.com*
Giuseppe Fallacara Politecnico di Bari, Dipartimento DICAR *giuseppe.fallacara@poliba.it*
Matteo Generelli CNC Fabrication Specialist, Generelli SA *matteo@generelli.ch*
Edoardo Tibuzzi AKT II, Associate Director *edoardo.tibuzzi@akt-uk.com*

Questa ricerca mostra le ultime esperienze progettuali nell'uso di pannelli a forma libera in pietra naturale, rinforzati attraverso l'uso di fibra di carbonio. La combinazione di questi due materiali consente di ridurre lo spessore dei componenti in pietra fino a pochi millimetri e il raggiungimento di grandi performance statiche, grazie all'utilizzo di avanzate tecnologie di progettazione algoritmica e macchine CNC robotiche.

Arredi in pietra, Marmo Palissandro, Stone Skin, Fibra di Carbonio, Stereotomia 2.0

This research shows the latest design experiences in the use of free-form panels made of natural stone, reinforced through the use of carbon fiber sheets on the back. The combination of these two materials allows reducing the thickness of the stone components up to few millimetres and the achievement of a great static performance, thanks the use of advanced algorithmic design technologies and robotic CNC machines.

Stone Furniture, Palissandro Marble, Stone Skin, Carbon Fibre, Stereotomy 2.0

M. Barberio Orcid id 0000-0001-8714-5306
G. Fallacara Orcid id 0000-0002-2291-6832
E. Tibuzzi Orcid id 0000-0002-7203-6585

118 → 129 ISSN 2531-9477 [online], ISBN 978-88-85885-02-8 [print]

Introduction

The paper describes the antecedent (Möbius Sofa) and the design process of an unique furniture, the Lapella Chair, made for "Stereotomy 2.0 and Digital Construction Tools", an event which was held in New York from April 16th to April 29th, 2018 at the New York Institute of Technology's School of Architecture and Design (SoAD). The aim of the event was to disseminate theoretical and practical culture related to stereotomic architecture, from its sixteenth-century origins to the latest design applications.

Stereotomy 2.0

While "Stereotomy 1.0" comprises the early development of the discipline primarily related to stonecutting, the new discipline, "Stereotomy 2.0", goes beyond this early concept to embrace contemporary design paradigms and materials. This relatively new field of research, called "digital stereotomy", was born in 2000 at the Politecnico di Bari (Italy) and has since spread throughout academic community worldwide. The diffusion of parametric modelling and digital fabrication tools created the ideal conditions to design and build new stereotomic architectures, which are typically characterized by considerable architectural and geometric complexity (Fallacara, Barberio, 2018b, p. 1).

"Stereotomy 2.0" has been theoretical defined by a recently published "Unfinished Manifesto" (Fallacara, Barberio, 2018a). Composed of ten points, the Manifesto describes the fundamental theoretical points underlying the "Stereotomic Design", understood as a new didactic discipline for schools of architecture and as a new design process useful for contemporary architectural design.

Among the ten point the fourth focused on material characterization of Stereotomy 2.0, theorising the possibility of using not only natural materials, but also artificial or hybrid ones: «In order to broaden the expressive possibilities of the discipline and overcome the limitations imposed by the individual materials, the use of composite material born from the union of materials with different and complementary characteristics is encouraged. Moreover, with Stereotomy 2.0 the specific use of heavy materials is not mandatory, allowing the use of light-weight materials» (Fallacara, Barberio, 2018a, p. 12).

The theoretical definition of this point was inspired by a series of experimental prototypes designed in recent years (Clifford, McGee, 2011; McGee et al., 2013; Diles, 2018), including a series of experiments on the conjunct use of thin stone and carbon fibre reinforcement (Fallacara, Barberio, 2016; Fallacara et al., 2016).

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Fabrication process of Möbius Sofa (Photos by Generelli SA, 2016)

Möbius Sofa

Möbius Sofa is inspired by the famous Möbius strip that is a surface with only one side and only one boundary. It can be realized as a ruled surface. It was discovered independently by the German mathematicians August Ferdinand Möbius and Johann Benedict Listing in 1858.

The research aims to investigate the architectural uses of free-form panels made of natural stone, reinforced through the use of carbon fiber (or glass fiber) sheets on the back, in order to build lightweight shells in granite or marble. The combination of these two materials allows reducing the thickness of the stone components up to few millimetres and the achievement of a great structural performance. The project is a collaboration between the New Fundamentals Research Group (Politecnico di Bari) and the Ticino-based company, Generelli SA.

Möbius Sofa represents the state-of-the-art of research into stone materials and manufacturing techniques. The seat is configured as continuous 2 centimetres thick bands of Perlato di Sicilia, reinforced by applying a layer of carbon fibre on the back and was exhibited in Marmomac Verona in October 2016. The bands are made up by assembling a few lightweight pieces manufactured using CNC machinery [fig. 01]. Their form emphasises the enormous unexplored potential of stone as a contemporary material for industrial design [fig. 02].

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Möbius Sofa
(Photos by Nicola Demaldi, 2017)

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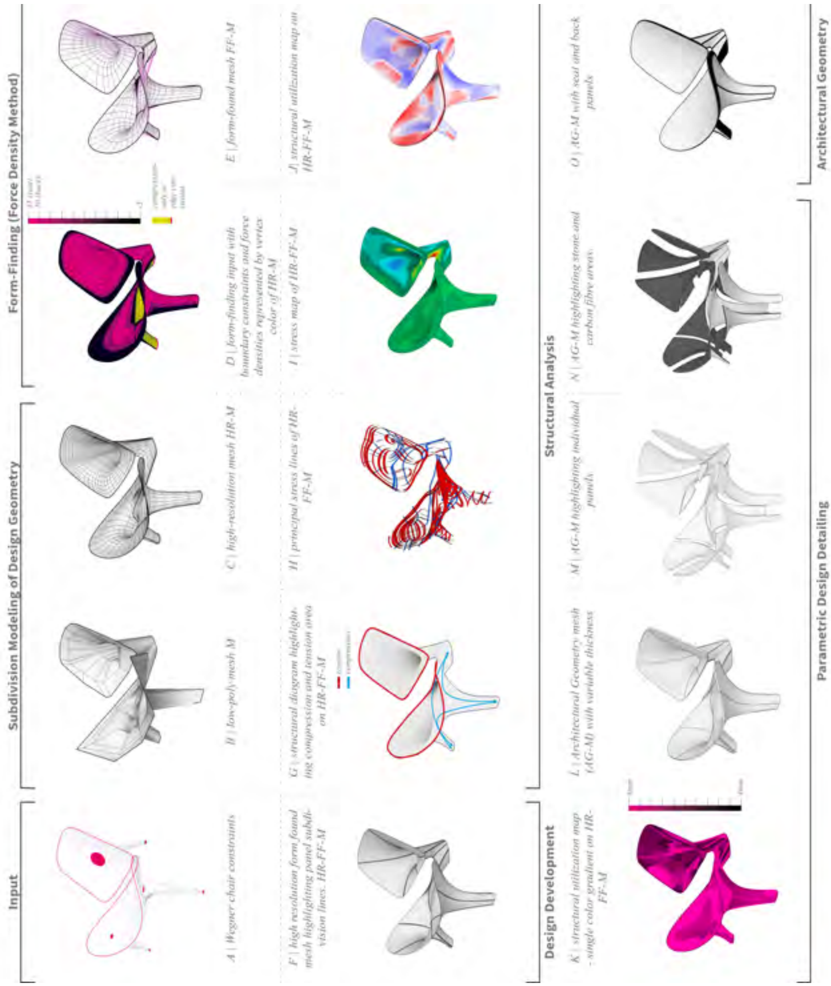
03
Zaha Hadid Architects' Principal Patrik Schumacher seating on Lapella (Photo by Gotham Fotografia, 2018)

Lapella Chair and the event "Stereotomy 2.0 and Digital Construction Tools"

Lapella Chair represents the evolution of the experiments carried out by NFRG and Generelli SA with Möbius Sofa. "Lapella" by Zaha Hadid Architects has been designed as the masterpiece of the whole event "Stereotomy 2.0 and Digital Construction Tools" held in New York in April 2018. The event has been conceived by Giuseppe Fallacara and edited with Christian Pongratz (Interim Dean of the School of Interdisciplinary Study and Education, NYIT), in collaboration with the New York Institute of Technology (Maria Perbellini, Dean of SoAD NYIT), New Fundamentals Research Group, Zaha Hadid CoDe and P.art from AKT II. The event included several activities in many locations in the New York City: a competition with workshops, a symposium and an exhibition. The exhibition held in the Par Excellence gallery presented the state-of-the-art research on digital stereotomy through physical models, prototypes and posters. Among the various projects the exhibition also included three prototypes of stone furniture, one made of massive stone and two of thin fibre-reinforced stone, including Möbius Sofa and Lapella (Colella, 2018). This relatively new axis of research (Schumacher, 2018) applies stereotomic techniques to the world of furniture design, thanks the latest generation of CNC machines and 3D modelling tools, which allow the creation of complex shapes informed by ergonomic data and optimised by structural analysis software developed in a full parametric environment.



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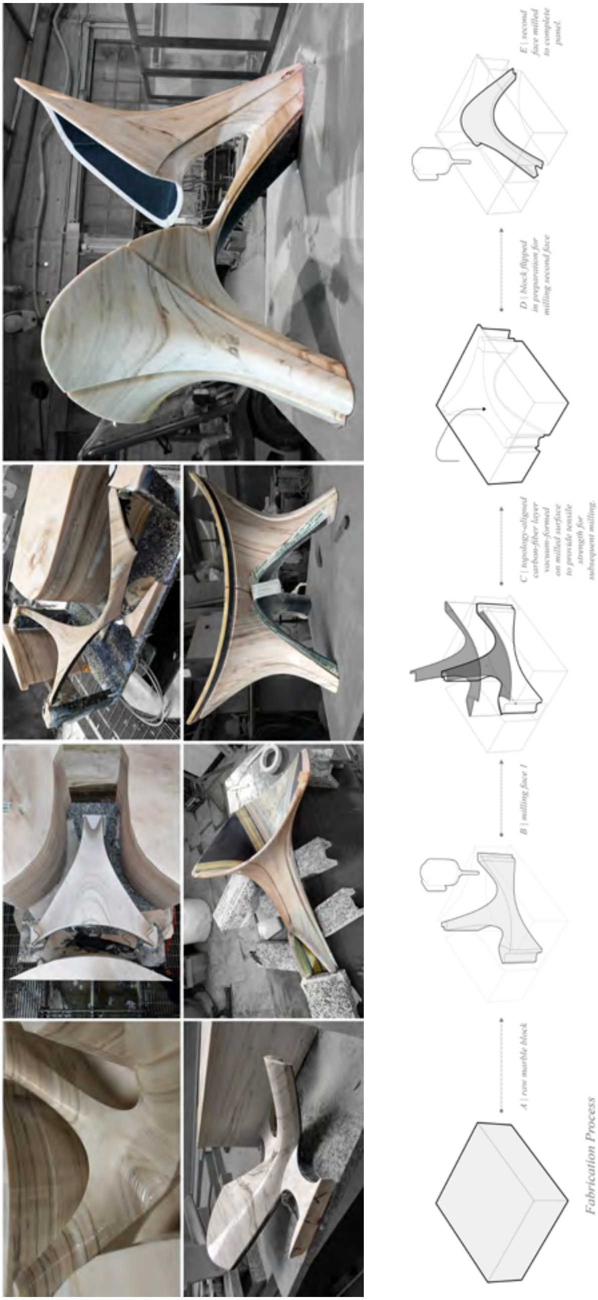
Lapella Chair design workflow
(ZHA CoDe, 2018)



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Lapella Chair (Photos by Gotham Fotografia, 2018)

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Lapella Chair: design and fabrication workflow

Lapella continues the investigations into structure and fabrication-aware tectonics by reinterpreting the iconic 1963 lounge chair by Hans J. Wegner [fig. 03]. The group retained the proportions, scale, and recline from the Danish design, whilst deploying contemporary stone tooling and carbon-fibre composites to create Lapella. Forged using precision CNC milling and the application of tailored textiles, it renders visible its own making and the forces that flow through its thin-shell skin.

Lapella continues the delving into the development of design tools that generate expressive geometries utilising lightweight material and structural performance. This tectonic approach casts the design of furniture within an architectural perspective-furniture becomes a precursor and human-scale test-bed to the full-scale deployment of novel material and manufacturing technology at an

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Fabrication process of Lapella Chair (Photos by Generelli SA, 2018)

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architectural scale. The design employs contemporary, state-of-the-art algorithmic [fig. 04] extensions to historic design techniques usually found in stone masonry of yesteryear. These stereotomic design techniques recuperate the historic utilisation of curvature to elegantly transfer weight and forces to ground along with organising the layout of material in relation to such force-flows. The thin, carbon-fibre-reinforced stone pieces are arranged to visually accentuate these formative logics of material and force (Bhooshan et. al., 2018).
The original design was envisaged in steam-bent plywood. The authors have revisited the Wegner chair in polished Palissandro Marble procured from Italy. The patented process of manufacture (Generelli, Generelli 2017) harnesses the compressive properties of stone and the tensile properties of carbon fibre to achieve unparalleled thinness, lightness, and structural performance [fig. 05].
To enable the parallel study of multiple loading configurations on an evolving design, structural analysis was delivered using AKT II's in-house parametric interoperability solution, Re.AKT. The analysis, and feedback with the stone fabricators Generelli SA, informed and incre-

07
Skeleton structure and exterior view (up); exterior and full-scale cladding prototype (down) (NYIT's students 2017-2018, Prof. Giuseppe Fallacara

mentally improved design parameters to address stone tolerances, curvature thresholds and mass distribution. At the same time, the design was modified via dynamic relaxation to minimise effects of bending within the form itself. The resulting optimised form demonstrates the thinnest and lightest structure capable under the given constraints.
The vaulted undercarriage performs in full compression, while neighbouring parts exhibit more varied degrees of tension and compression. This gradation of stress and strain internal to the parts is articulated through varied thicknesses of the stone, and informed the face selection for application of tensioning carbon fibres.
Destructive testing was commissioned and performed by The University of Westminster to understand the compressive, tensile and out-of-plane behaviour of the composited stone and carbon-fibre layers. Non-linear, discrete element analysis (DEA) models were generated and calibrated from the results using specialist software (Itasca 3DEC). This process captures the behaviour of the natural stone faster and more accurately than traditional methods, and is also an interesting example of design influenced by a close collaboration between architects, structural engineers and fabricators.
The fabrication of the parts that forms the chair consists of the following steps [fig. 06]:
- a solid block containing the piece to be fabricated is taken on the horizontal plane;
- the block is moulded until the complete milling of the backside of the panel;
- the milled surface is reinforced by carbon fibre or glass fibre which are glued through vacuum bagging technique;
- the fibre-reinforced block is rotated and milled on the other side, until the panel desired thickness is achieved;
- all the parts are glued together;
- the stone and the carbon fibre are polished.

Conclusion: future developments in the architecture fields

The presented technology can be used in architecture for structural and non-structural panels. Structural panels refer to the use – in the architectural field – of self-bearing cladding panels without requiring any additional structural support. If appropriately shaped, the panels can be used to create arches, vaults and single and double curvature shells and single or double shell (that is, by coupling two panels). Non-structural panels instead refer to panels lying on a structural support. In this case, the carbon fibre sheet is mainly used for safety reasons to prevent that

a possible stone crack could damage a third party. These panels can be used in architecture, to make stone, ventilated facades, roofing, etc.
An example of the application of this technology in the field of architectural design and construction is the New School of Health Professions at NYIT, Old Westbury, Long Island, New York, designed by Master's students of the New York Institute of Technology's School of Architecture and Design under the supervision of Prof. Giuseppe Fallacara (2018). The project reflects and creates new solutions for a contemporary building expressly designed for health, education and didactics for the health professions. The construction technology offers new innovative applications for traditional materials, in particular the building is covered with thin double-curved granite panels reinforced with glass fibre. The project proposal was exhibited during the event "Stereotomy 2.0 and Digital Construction Tools". For the exhibition the company Generelli SA realized a full scale thin cladding panel of granite and carbon fiber [fig. 07].

ACKNOWLEDGMENTS AND CREDITS

The overall structure and narrative of this paper are the result of the combined work of all the authors. Sect. 1, "Introduction", was written by M. Barberio; Sects. 2 and 3 were written by G. Fallacara and M. Barberio; Sects. 4 and 5 were written by S. Bhooshan and E. Tibuzzi and edited by G. Fallacara, M. Barberio and M. Generelli; Sects. 6 were written by G. Fallacara and edited by the other authors. The authors consider their individual contributions to whole to be equal.
The Möbius Sofa was designed by Giuseppe Fallacara with New Fundamentals Research Group (Maurizio Barberio) and Daniele Malomo; and fabricated by Generelli SA (Matteo Generelli). Perlato di Sicilia was supplied by MGI Sicilmarmi.
The Lapella Chair was designed by Zaha Hadid Architects (Patrik Schumacher) with ZH CODE (Shajay Bhooshan, Vishu Bhooshan, Henry David Louth, Marko Margeta, Taole Chen); engineered by AKT II P.Art (Edoardo Tibuzzi, Lorenzo Greco); and fabricated by Generelli SA (Matteo Generelli) with the support of New Fundamentals Research Group (Giuseppe Fallacara, Maurizio Barberio).

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