Gennaro Senatore

Habil. PhD MRes MSc MEng (Hons)

Date, place of birth	28/05/1982, Salerno, Italy
Work Address	University of Stuttgart, Institute for Lightweight Structures and Conceptual Design (ILEK), Pfaffenwaldring 7, 70569 Stuttgart, Germany
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Language	English (C2 – Cambridge Certificate of Proficiency), Italian (native)

Biography

Gennaro Senatore is **Head of Research in Adaptive Structural Systems** at the Institute for Lightweight Structures and Conceptual Design (ILEK), University of Stuttgart. He previously held research leadership roles at the Swiss Federal Institute of Technology Lausanne (EPFL), University College London, and Expedition Engineering in London. He has led interdisciplinary teams and directed research projects funded by major European agencies and industry partners, building strategic collaborations across academia and practice.

His research integrates structural mechanics and control through computational synthesis, advancing *adaptive structural systems* as a design degree of freedom for ultra-lightweight, low-carbon, and resilient solutions for the built environment. He has authored more than 35 publications in leading peer-reviewed scientific journals. His methods have been validated through full-scale prototypes.

In teaching, he has developed new courses on ultra-lightweight construction, design through component reuse, and algorithmic modeling for computational workflows. To support evidence-based digital design education, he developed *PushMePullMe*, an interactive analysis tool that combines game mechanics with numerical methods to make structural behavior and performance tradeoffs legible to students.

In practice, he has contributed to *high-profile international projects* through advanced computational workflows for the conceptual design of complex structural systems. As part of his commitment to knowledge transfer and methodological innovation, he served as a **Lead Expert** appointed by the European Commission's Joint Research Centre to develop the *New European Bauhaus Self-assessment Method*, a policy-aligned framework integrating environmental, functional, aesthetic, social, governance, and economic performance.

Expertise

Computational Structural Mechanics, Computational Design Synthesis, Adaptive Structural Systems, Structural and Topology Optimization, Sustainable Design and Construction, Cyber-Physical Systems, Programming (MATLAB, Python, LabView, C#, Java).

Habilitation and Academic Qualification

Habilitation (venia legendi) – *Adaptive Structural Systems & Computational Structural Mechanics* since 08/2025
University of Stuttgart (Full Professor level)

National Scientific Qualification – *Structural Mechanics (08/B2)* since 06/2022
Italian Ministry of University and Research, Fascia II (Associate Professor level)

Licensure and Accreditation

Registered Professional Engineer (Ingegnere, Sezione A), Ordine degli Ingegneri, Salerno, Italy since 2006
Sectors**:** Civil and Environmental, Industrial, Information Engineering. Fully qualified for the design, supervision, consultancy, and certification of complex engineering works with **full professional and legal responsibility** under Italian law.

Education

Doctor of Engineering (PhD equivalent) in Urban Sustainability and Resilience, *University College London* 11/2010 – 08/2016
Thesis title: "Adaptive Building Structures"
Academic advisors (UCL): Prof Philippe Duffour, Prof Sean Hanna. Industrial advisors (Expedition Engineering): Dr Pete Winslow, Prof Chris Wise. Examiners: Prof Werner Sobek (University of Stuttgart), Prof Chris Williams (Chalmers University of Technology)

Master of Science in Urban Sustainability and Resilience, *University College London* 09/2009 –11/2010
Thesis title: "Adaptive Responsive Structures"
Academic advisors (UCL): Prof Philippe Duffour, Prof Sean Hanna

Master of Science in Emergent Technologies and Design, *The Architectural Association of London* 09/2007 – 09/2008
Thesis title: Design of Structures through Evolutionary Strategies. Grade: Distinction
Advisors: Dr Mike Weinstock, Prof Achim Menges, Prof Michael Hensel. Examiner: Prof Branko Kolarevic (University of Calgary)

Master of Science in Computing and Design, *The University of East London* 09/2007 – 09/2009
Thesis title: Morphogenesis of Structural Configurations. Grade: Distinction
Advisors: Prof Paul Coates, Dr. Christian Derix. Examiner: Prof Mark Burry (RMIT)

Master of Mechanical Engineering (Honors), *Federico II University* 09/2000 – 03/2006
Thesis title: FEM Modelling of Drilling Rods. Grade: 110/110 summa cum laude
Advisors: Prof Giuseppe Godono, Prof Renato Esposito, Dr Enrico Armentani

Employment History

Senior Research Group Leader (TV-L E14-6), *University of Stuttgart* since 10/2021

Head of Research in Adaptive Structural Systems, Institute for Lightweight Structures and Conceptual Design (ILEK)

Research lead for developing analytical, computational, and experimental methods that integrate structural optimization and control system design to enable ultra-lightweight, low-carbon, and resilient structural systems. Application development has included *adaptive floor slabs*, *multi-story buildings* and *bridges*. Supervision responsibilities include one postdoctoral researcher, one PhD researcher, two research assistants, and four MSc projects (see Supervision).

Lead Expert - New European Bauhaus (NEB), *Joint Research Center - European Commission* (100 days) 09/2022 – 09/2024

Led the development and served as lead author of the *New European Bauhaus Self-assessment Method* for the main area of Emerging Technologies, with responsibility for the conceptual framework, methodological structure, and synthesis of expert contributions. Coordinated the recruitment and work of five sub-area experts: Prof. *Gian Paolo Cimellaro* (Politecnico di Torino), Prof. *Burcin Becerik* (University of Southern California), Prof. *Nikos Lagaros* (National Technical University of Athens), Prof. *Ed Manley* (University of Leeds), and *Adrian Campbell* (Changebuilding).

Research Group Leader, *Swiss Federal Institute of Technology (EPFL)* 01/2017 – 11/2020

Postdoctoral Research Associate, Applied Computing and Mechanics Laboratory (IMAC)

Co-director of three PhD theses and four MSc projects (see Supervision)

Research Associate, *University College London* 05/2015 – 11/2016

Research Lead, knowledge transfer project *Discovery to Use* - Adaptive Design Solutions (see Funded Research Projects).

Head of Computational Design & Research, *Expedition Engineering* 03/2014 – 04/2015

Initiator Lead Developer of *PushMePullMe* – an interactive educational tool for teaching integrated structural analysis and design

Initiator and Lead Developer of *Make A Scape* – an educational game to teach fundamental principles of structural mechanics.

Research Engineer, *Expedition Engineering* (35% full-time equivalent) 09/2009 – 03/2014

Parametric 3D design and structural analysis of the complex geometry of the *Emirates Air Line* towers.

Parametric 3D design and structural analysis of *Chiswick Park Footbridge*.

Led computational design of the *Biomimetic Office* – office building inspired by biological structures and developed through multi-objective optimization to achieve performance-driven architectural form.

Led computational design of the *Forum Pattern* – highly intricate, nature-inspired geometric brand expression for the University of Exeter.

Design Engineer, *ARUP London - Advanced Geometry Unit* 05/2007 – 10/2007

Funded Research Projects

Adaptive Facades and Structures for the Built Environment of Tomorrow (CRC1244) 10/2021 – 12/2025

Senior Scientist. Research lead for the ILEK contribution to sub-projects A04 (*adaptive floor slabs*), A06 (*multi-story buildings*), and C07 (*bridges*), jointly developed with ISYS and IBB at the University of Stuttgart.

Funding Institution: German Research Foundation (Deutsche Forschungsgemeinschaft, DFG).

Structural Adaptation through Large Shape Changes 10/2018 – 09/2020

Research Group Leader. Development of computational methods to design load-bearing structures that mitigate the response under peak loads through *shape morphing* — enabled by large deformations and geometrically nonlinear behavior.

Funding Institution: Swiss National Science Foundation (SNSF), CHF 230,000

Note: First author of the research plan but not official PI because the Ph.D. was awarded less than four years from the time of application, which, for the SNSF, is the minimum requirement. The PI, Prof Ian Smith (EPFL), will confirm this statement.

Structural Adaptation through Large Shape Changes (experimental agenda) 10/2018 – 09/2020

Research Group Leader. Development and experimental validation of a novel *shape morphing* bridge prototype,

Funding institution: Arup Global Research Challenge, CHF 70,000; EPFL - ENAC Internal Funding Call, CHF 60,000.

Adaptive Joints with Variable Stiffness 01/2017 – 01/2018

Co-Principal Investigator. Development and experimental testing of a new type of *semi-active control device* for vibration control in collaboration with Eindhoven University of Technology and Delft University of Technology.

Funding Institution: 4TU Federation Lighthouse Project (Holland), €50,000

Discovery to Use - Adaptive Design Solutions 05/2015 – 11/2016

Research Group Leader. Knowledge transfer project focused on promoting the adoption of adaptive design strategies in civil engineering. Conducted in collaboration with Buro Happold and Jarlso Telecom Solutions.

Funding Institution: Engineering and Physical Sciences Research Council (UK), £60,000

Research and Development Enabling Fund 05/2014 – 05/2015

Principal Investigator. Development and experimental validation of a 6-meter-span adaptive truss prototype for shape control and stress redistribution under variable loading.

Funding Institution: Institution of Civil Engineers (ICE), £25,000

Further information can be accessed at: *gennarosenatore.com/funding_and_awards*

Supervision

University of Stuttgart

Supervision of postdoctoral researcher 10/2021 – 12/2024

Researcher: Dr Arka Reksowardojo. Project: "Design and retrofit methods for adaptive floor systems"

Supervision of PhD researcher Since 10/2021

Researcher: Francesco Virgili. Thesis title: "Performance-based design of adaptive high-rise structures with dynamic effects"

Supervisor of MSc project 05/2024 – 12/2025

Student: Lennon Toeche-Mittler. Thesis title: "Geometry-based multi-scale topology optimization"
Student: Marc Sterns. Thesis title: "Multi-material topology optimization for bridge structures"
Student: Filippo Scanderbeg. Thesis title: "Multi-material topology optimization for floor structures"
Student: Han Zhang. Thesis title: "Component Reuse in Heritage Reconstruction: Enhancing Preservation and Innovation"

Swiss Federal Institute of Technology (EPFL)

Supervision of postdoctoral researcher 04/2019 – 11/2020

Researcher: Dr Yafeng Wang. Project: "All-In-One optimization methods for adaptive structures"

Supervision of PhD researcher 01/2017 – 11/2020

Researcher: Arka Reksowardojo. Thesis title: "Large and reversible shape changes as a strategy for structural adaptation"
Researcher: Jan Brütting. Thesis title: "Optimum design of low environmental impact structures through component reuse"
Researcher: Qinyu Wang. Thesis title: "Variable stiffness and damping structural joints for semi-active vibration control"

Supervision of MSc project 09/2018 – 07/2020

Student: Francesco Virgili. Thesis title: "Design and vibration control of adaptive structures"
Student: Vincent Lestang. Thesis title: "Adaptive timber structures"
Student: Julien Lebet. Thesis title: "Interactive and real-time structural simulation with beam and shell elements"
Student: Xavier Choitel. Thesis title: "Interactive and real-time structural simulation with volumetric elements"

Supervision of visiting PhD researcher 05/2019 – 10/2019

Student: Kazuki Hayashi. Project: "Development of control methods for adaptive structures using reinforcement learning."

Chalmers University of Technology

Supervision of MSc project 09/2012 – 09/2013

Student: Alexander Sehsltrom. Department of Applied Mechanics. Thesis title: "Multi-objective structural topology optimization"

Teaching

University of Stuttgart - ILEK

Introduction to Academic Research and Scientific Writing Since 04/2022

This course introduces students to the principles and practices of scientific writing, covering information literacy, research planning, and structuring of theses and articles through interactive exercises and critical analysis.
Role: course manager and lecturer, 4 hours per week. Class size: 20 - 30.

Digital Design Since 04/2022

This course teaches parametric and algorithmic modeling to structure early-stage design processes as computational workflows, enabling iterative, multi-objective design exploration across engineering domains.
Role: course co-initiator, co-manager and lecturer, 2 hours per week. Class size: 30 - 50.

Ultralightweight Construction Since 10/2022

This course transfers basic principles and methods for designing high-performance structural systems, such as ultralight or adaptive structures, including optimization techniques that account for mechanical constraints, environmental impact, and component reuse.
Role: course co-manager and lecturer, 4 hours per week. Class size: 30 - 50.

Swiss Federal Institute of Technology (EPFL)

Information Science in Engineering 04/2018 – 06/2018

Institute of Civil Engineering, Doctoral Program. **Role**: guest lecturer. Class size:15+.

Design of structures 10/2018 – 12/2018

School of Architecture. **Role**: guest lecturer, 8 hours. Class size:100+.

Semester project at the Space Engineering Center (eSpace) 10/2017 – 05/2018

Project: design of an adaptive structural system to capture unresponsive satellites orbiting Earth.
Role: supervision, 4 hours biweekly. Class size:10+.

University of Bergamo 09/2013 – 06/2015

Computational Methods in Architectural Design, Faculty of Building Engineering.
Introduction of computational methods for architectural design, with a focus on parametric modeling and structural analysis.
Role: guest lecturer, 8 hours monthly. Class size: 30 to 50.

University of East London 09/2009 – 06/2010
MSc in Architecture, Computing and Design. School of Architecture, Computing and Civil Engineering.
Computational methods for integrated parametric modeling and co-design of structure and geometry (e.g., structural form-finding), combining algorithmic workflows with performance-based analysis. **Role**: guest lecturer, 2 hours biweekly. Class size:10+.

The Architectural Association of London 09/2008 – 06/2009
MSc in Emergent Technologies and Design.
Computational methods for integrated parametric modeling and co-design of structure and geometry (e.g., structural form-finding), combining algorithmic workflows with performance-based analysis. **Role**: guest lecturer, 2 hours biweekly. Class size: 20 to 30.

Awards

Hangai Prize (best paper award - co-author), International Association for Shell and Spatial Structures 10/2019
Arup Global Research Challenge, £50,000 (8 grants awarded from 180+ applicants) 06/2018
Engineering Impact Award, National Instruments 10/2016
Future Technology Award, New Civil Engineer 05/2016
Italy Made Me Research Award, Association of Italian Scientists UK (AISUK) 05/2015
Research Award, £6,000. Institution of Structural Engineers, London, UK 2013
Hangai Prize (best paper award – first author), International Association for Shell and Spatial Structures 09/2011
Merit scholarship international, €10,000, Regione Campania, Italy 09/2008 – 09/2009
Merit scholarship, £5,000, The Architectural Association London 09/2007 – 09/2008
Merit scholarship, €12,000, Federico II University, Naples, Italy 09/2000 – 09/2006

Editorial Contribution & Scientific Reviewing

Academic Editor / Advisory Board, *Structural Control and Health Monitoring* since 2024
Guest Editor, Journal of Constructional Steel Research, Special Issue on *Large-Span Steel Structures* 2024 – 2025
Guest Editor, Frontiers in Built Environment, Special Issue on *Design and Control of Adaptive Civil Structures* 2019

Individual Scientific Reviewing (selected journals)
Computational Methods in Applied Mechanics and Engineering, Acta Mechanica, Transaction on Mechatronics since 2023
Computers & Structures, Smart Materials and Structures, Engineering Structures, Engineering Optimization since 2018
The Journal of Structural Engineering (ASCE), Structural and Multidisciplinary Optimization, Composite Structures since 2017

Organization of Conferences

Principal Organizer 09/2019
Special session Adaptive Structures: Design, Optimization and Control at the 7th International Conference on Structural Engineering, Mechanics and Computation, 2019, Cape Town, South Africa.

Scientific Committee Member 06/2018
25th International Workshop on Intelligent Computing in Engineering Lausanne, Switzerland.

Active Memberships

International Correspondent Member 2017 – 2021
CRC1244 Adaptive Shells and Structures for Tomorrow's Built Environment, University of Stuttgart
International Association for Shell and Spatial Structures (IASS) since 2011
German Association for Computational Mechanics since 2017

Summary of Scientific Achievements

Data retrieved in November 2025

	Number	Data Base	Start	End
Peer-reviewed journal articles	35	Scopus	2015	2025
Peer-reviewed conference articles	12	Scopus	2011	2025
Contribution to Books [scientific]	1	*DOI*	2018	2018
Books [Manual/Standards]	1	*DOI*	2022	2024

Total Journal Impact Factor	144.2
Average Journal Impact Factor	4.37
Total Citations (Scopus)	1,148
Average citations per product	1,148/47 ≈ 24.5
Hirsch (H) Index (Scopus)	22
Academic age (PhD defense in August 2016)	9.3 years
Adjusted academic age (excluding 2.6 years of professional practice)	6.6 years
Normalized H index by academic age	22/9.3 = 2.4
Adjusted Normalized H index	22/6.6 = 3.3

Selected Publications

Data retrieved in November 2025

Publication	Journal IF	Citations (Scopus)
[1] K.A. Canny, **G. Senatore**, and L. Blandini, "Investigation of retrofit strategies to extend the service life of bridge structures through active control," Journal of Bridge Engineering (ASCE), vol. 30 (2), 2025, doi: *10.1061/JBENF2.BEENG-6925*. **Role**: corresponding author and Research Lead.	3.5	8
[2] **G. Senatore**, Y. Wang, "Topology Optimization of Adaptive Structures: New Limits of Material Economy," *Computer Methods in Applied Mechanics and Engineering*, vol. 422, 2024, doi: *10.1016/j.cma.2023.116710*, (Highly Cited Paper).	7.3	44
[3] A.P. Reksowardojo, **G. Senatore**, M. Bischoff, L. Blandini, "Design and control benchmark of rib-stiffened concrete slabs equipped with an adaptive tensioning system," *Journal of Structural Engineering*, 2023, doi:*10.1061/JSENDH.STENG-12320*. **Role**: corresponding author and Research Lead.	3.9	9
[4] A.P. Reksowardojo, **G. Senatore**, A. Srivastava, C. Carroll and I. F. C. Smith, "Design and testing of a low-energy and -carbon prototype structure that adapts to loading through shape morphing," *International Journal of Solids and Structures*, vol. 252, 2022, doi: *10.1016/j.ijsolstr.2022.111629*. **Role**: shared first author, Research Lead, Co-Director of Arka Reksowardojo PhD thesis.	3.8	27
[5] Q. Wang, **G. Senatore**, K. Jansen, A. Habraken and P. Teuffel, "Seismic Control Performance of a 3-Story Frame Prototype Equipped with Semi-Active Variable Stiffness and Damping Structural Joints," *Earthquake Engineering and Structural Dynamics,* vol. 50, no. 13, p. 3379-3402, 2021, doi: *10.1002/eqe.3514*. **Role***:* shared first author and Research Lead, Co-Director of Qinyu Wang PhD thesis.	5.0	21
[6] Y. Wang and **G. Senatore**, "Extended Integrated Force Method for the analysis of prestress-stable statically and kinematically indeterminate structures," *International Journal of Solids and Structures*, vol. 202, p. 798-815, 2020, doi: *10.1016/j.ijsolstr.2020.05.029*. **Role**: corresponding author and Research Lead.	3.8	25
[7] J. Brütting, J. Desruelle, **G. Senatore** and C. Fivet, "Design of Truss Structures through Reuse," *Structures,* vol. 18, pp. 128-137, 2019, doi: *10.1016/j.istruc.2018.11.006*. **Role**: Co-Director of Jan Brütting's PhD thesis. Co-led the conceptual development of the work and coordinated the manuscript revision process. This role can be confirmed by Prof. Corentin Fivet (SXL Lab, EPFL) upon request.	4.3	121
[8] **G. Senatore**, P. Duffour and P. Winslow, "Synthesis of Minimum Energy Adaptive Structures," *Structural and Multidisciplinary Optimization,* vol. 60(3), p. 849-877, 2019, doi: *10.1007/s00158-019-02224-8*.	4.0	78
[9] **G. Senatore**, P. Duffour, P. Winslow and C. Wise, "Shape Control and Whole-Life Energy Assessment of an "Infinitely Stiff" Prototype Adaptive Structure," *Smart Materials and Structures,* vol. 27(1), 2018, doi: *10.1088/1361-665X/aa8cb8*.	3.8	76
[10] **G. Senatore** and D. Piker, "Interactive real-time physics: an intuitive approach to form-finding and structural analysis for design and education," *Computer-Aided Design,* vol. 61, p. 32-41, 2015, doi: *10.1016/j.cad.2014.02.007*.	3.1	40

Major Achievements

Gennaro Senatore

1. New computational design synthesis methods, including first integrated structure-control optimization formulations, unifying structural mechanics and control for adaptive, low-carbon structural systems.
2. Demonstrated performance gains through adaptivity, validated on large-scale prototypes.
3. Circular construction: new computational design methods enabling structurally efficient reuse under material availability limits.
4. Research leadership in interdisciplinary teams, translating methods into practice-facing demonstrators and tools.
5. Teaching innovation at the interface of structural mechanics, computation, and design, including interactive learning tools.
6. Knowledge transfer through leadership contributions to the *New European Bauhaus* self-assessment method.

Key Research Contributions

Ultralightweight, Low-Carbon and Resilient Structures through Adaptivity

This research advances a novel paradigm at the intersection of structural mechanics, control engineering, and sustainable design, focused on the development of adaptive load-bearing structures that offer enhanced performance and reduced environmental impact compared to conventional passive systems. A **substantial share of life-cycle emissions is embodied**, arising from material production, construction, transportation, and demolition. Nonetheless, **civil structures are typically overdimensioned** to withstand rare events (e.g., earthquakes and strong winds), resulting in underutilization of structural capacity for most of their service life.

To address this inefficiency, the research introduces new computational methods for the integrated design of structures equipped with sensing and actuation systems capable of modifying internal force flows and geometric configurations in response to external stimuli. The proposed design framework combines structural layout and actuator placement optimization with the objective of **minimizing whole-life energy** [1] or equivalent carbon, accounting for both embodied and operational components. Actuation is used to redistribute internal forces, reducing peak stresses and maintaining deformations within serviceability limits. In well-designed systems, a small amount of operational energy, deployed only during rare high-intensity events, enables significant savings in embodied energy and material mass. These structures carry ordinary service loads passively, relying on active control only when necessary. In the event of power loss or control failure, structural safety is preserved, though serviceability criteria (e.g., deflection limits) may be temporarily relaxed [2], [3].

A key contribution is the development of the **first formulation for the simultaneous optimization of topology, sizing, and actuator layout**, termed the **All-In-One** (AIO) approach, which yields globally optimal solutions via mixed-integer programming (MIP) [4]. Computational studies show that active control enables the realization of fully stressed forms, akin to Michell trusses, that would otherwise be infeasible under conventional displacement and compatibility constraints (Figure 1). When limit states such as deflection and buckling are considered, adaptive solutions approach fully stressed configurations while satisfying critical performance requirements.

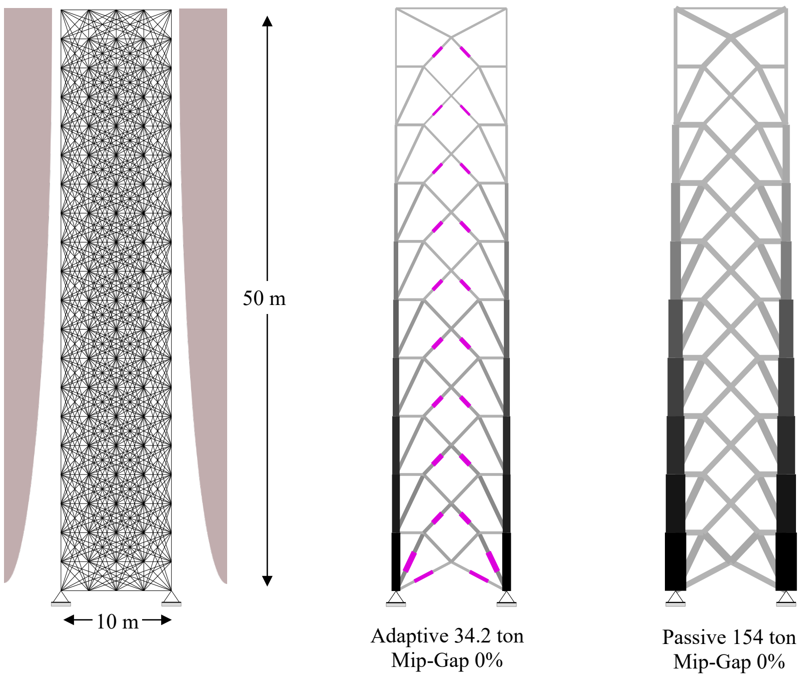

Figure 1 AIO Structure-Control Topology Optimization: a) ground structure, b) adaptive, and c) passive [4]; video demonstration

The research also explores geometric nonlinear effects to enable **real-time shape morphing** — adapting to optimal configurations as load conditions vary. This strategy promotes stress homogenization, resulting in substantial reductions in embodied energy and improved **damage mitigation and recovery** [5], [6]. Numerical simulations have demonstrated reductions of 50–70% in whole-life energy consumption, embodied carbon, and material mass across a range of structural typologies, including slender high-rise buildings, long-span bridges, and lightweight roof systems. Applications include **rib-stiffened floor systems** [7] and actively controlled **high-speed rail bridges** [8]. Further studies confirm that reducing peak stresses through active retrofit components can substantially **extend service life** in aging bridge structures [9]. Experimental validation was conducted on cantilevered and simply supported slender spatial structures (6 m span, 1 m width, span-to-depth ratio > 35:1), equipped with linear actuators, strain gauges, and optical tracking systems (Figure 2). A real-time control framework **integrating physics-based modeling with machine learning techniques**, including **kernel methods** and **neural networks**, was developed to mitigate model-form uncertainty and enable accurate shape adaptation under realistic conditions [10], [11]. Experimental results confirmed the effectiveness of the approach and validated key numerical predictions. These prototypes have been exhibited internationally and are currently used in ongoing research at the Institute for Lightweight Structures and Conceptual Design (ILEK), University of Stuttgart.

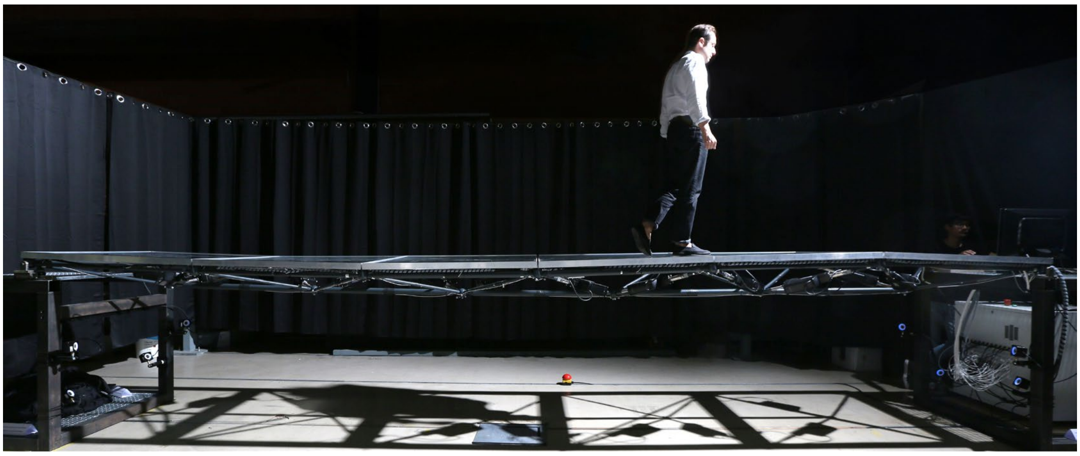

Figure 2 Shape-morphing bridge prototype, EPFL IMAC laboratory, [11]; video demonstration

Ongoing experimental development is being carried out on a 10 m × 6 m ultralightweight adaptive rib slab prototype equipped with active tendons that counteract stress and displacement induced by of out-of-plane loading by generating compensating bending moments [7]. Figure 3 documents the progression from conceptual design to **full-scale realization**, including the tendon layout and rib geometry, the integrated void-former and reinforcement system, and the constructed and demolded slab prior to instrumentation. This work represents the **first experimental investigation** of structural adaptivity in reinforced concrete components at this scale.

Overall, this research establishes a new foundation for high-performance, low-impact structural systems. It introduces innovative configurations that **redefine material and energy efficiency**, supports advanced retrofitting strategies for aging infrastructure, enhances damage recovery and resilience in strategic facilities, and enables unprecedented performance in ultra-slender high-rises, long-span bridges, and lightweight roof systems. More broadly, adaptive structures **shift the life-cycle energy balance** by reducing embodied demand upfront and deferring a comparatively small operational energy requirement to the future, thereby lowering total life-cycle emissions and reducing the environmental footprint of the built environment.

Further information can be accessed at: *gennarosenatore.com/research/adaptive_structures*

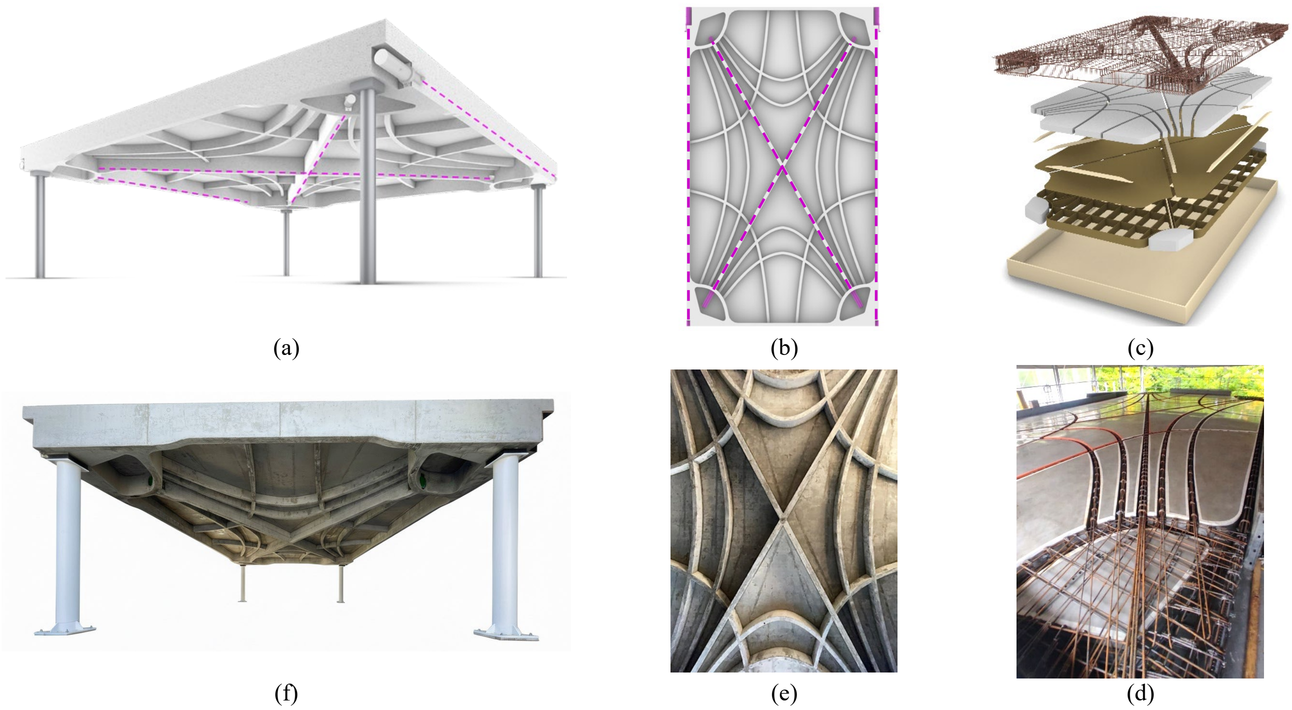

Figure 3 Adaptive rib slab prototype a) and (b) conceptual views with active tendons highlighted; (c) exploded view of the aluminum void formers and reinforcement; (d) reinforcement and tendon ducts prior to concreting; (e) detail of the demolded rib geometry after casting; (f) completed and demolded full-scale slab prototype prior to instrumentation.

Vibration Control through Variable Stiffness and Damping Structural Components

Most existing vibration-control solutions rely on external devices that require complex installation and detailing. This work introduces a **novel variable stiffness and damping control concept** that effectively mitigates the dynamic response of load-bearing structures under a wide range of excitations, including resonance, wind, seismic, and pedestrian- or traffic-induced loading**.** The device, referred to as an *adaptive joint* [12]**,** is inherently integrated into the load-bearing system by functioning as a structural connection. The joint operates in two states: a locked state, in which it behaves as a moment connection, and a released state, in which it behaves as a pin. The transition between these states is achieved through stiffness control enabled by a **solid-state actuation mechanism intrinsic to the material**. The joint consists of a polyurethane-based shape memory polymer (SMP) core reinforced with an SMP–aramid skin. When thermally actuated to the SMP transition range, the material undergoes a glassy-to-rubbery phase change, resulting in a pronounced stiffness reduction accompanied by increased damping due to viscoelastic effects. This controllable variation of mechanical properties enables modulation of natural frequencies and damping ratios, forming an effective **semi-active vibration control strategy**.

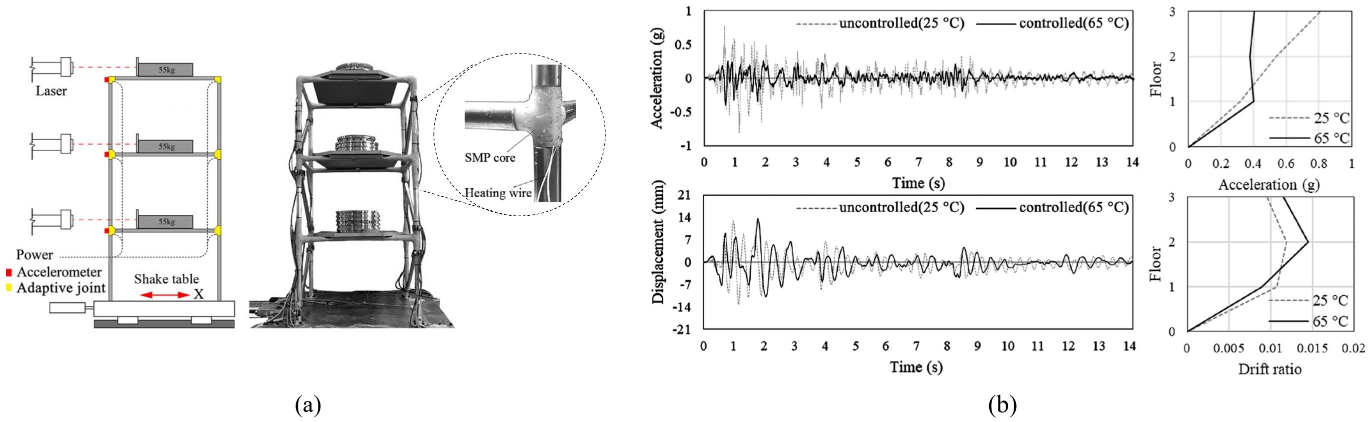

Figure 4 Adaptive joint shake-table validation: (a) 1:10 scale three-story frame prototype; (b) uncontrolled (25 °C) versus controlled (65 °C) response, showing reduced accelerations, displacements, and interstory drifts.

Numerical simulations of a three-story frame under seismic loading show peak acceleration reductions of up to 87% compared to the uncontrolled case [13]. Shake-table tests on a 1:10 scale three-story frame equipped with twelve adaptive joints (Figure 4) confirm an increase in structural damping from 2.6% to 11.3% and a shift in the first modal frequency of up to 37%. Depending on the excitation, **top-story acceleration and base shear are reduced by 43–50% and 35–51%,** respectively. The adaptive joint concept is broadly applicable to structures subjected to dynamic loading and has resulted in a provisional patent application.

Further information can be accessed at: *gennarosenatore.com/research/semiactive_vibration_control*

Design of Low-Environmental-Impact Structures through Component Reuse

This research proposes a computational methodology for designing low-environmental-impact load-bearing structures **through component reuse**. As urban transformation accelerates demolition and new construction, the existing building stock can be regarded as a substantial reservoir of reusable structural elements. Reusing components across multiple service cycles reduces material consumption, energy demand for reprocessing, and waste generation, in line with **circular-economy principles**. **Designing for reuse** differs from conventional practice: it is an **inverse process** in which structural layout emerges from the geometry and mechanical properties of available elements (e.g., cross-sections and lengths), rather than from predefined design choices [14], [15].

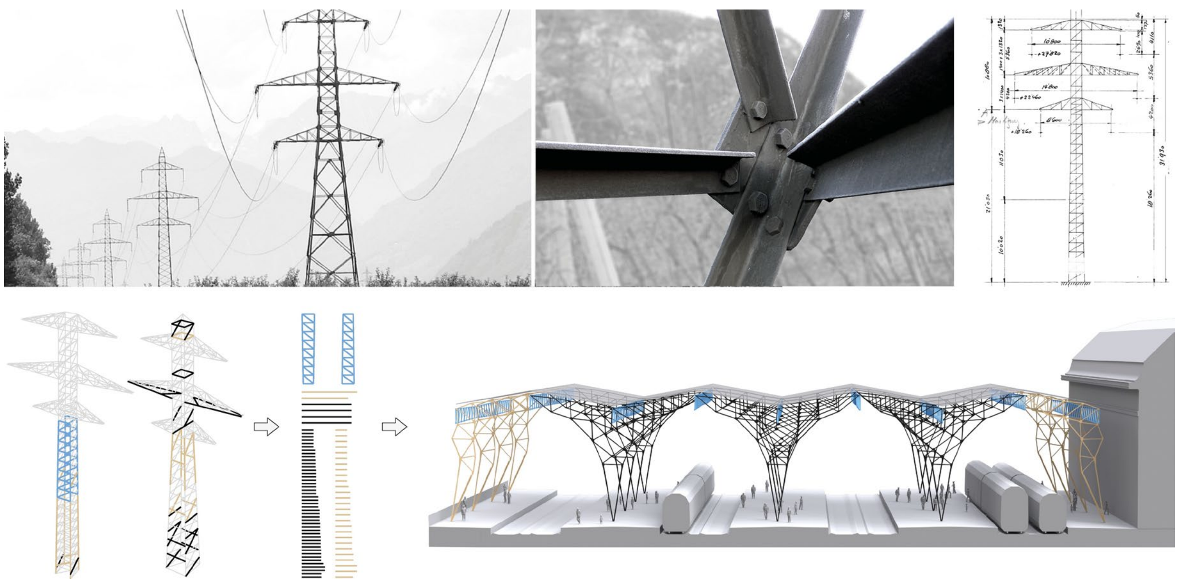

Figure 5 Stock-constrained design through reuse [14]

The main contribution lies in the formulation of discrete structural optimization methods for spatial trusses and frames that maximize the effective use of reclaimed element stocks. Environmental impact (EI) is minimized through the coupled optimization of stock-element assignment, structural topology, and geometry under standard strength and serviceability constraints. EI is quantified using Life Cycle Assessment (LCA), accounting for deconstruction, reconditioning, and transport processes [16]. Stock assignment and topology optimization are formulated as a Mixed-Integer Linear Programming problem, enabling globally optimal solutions and rigorous benchmarking across different stock compositions and LCA assumptions. Subsequent geometry optimization further reduces EI by minimizing cut-off waste. The methodology accounts for spatial and temporal variability in element availability and has been demonstrated on roof trusses and multi-story frames using realistic inventories derived from deconstructed buildings. Results have shown that:

- Solutions made from reused steel elements achieve up to 60% EI reduction compared to solutions made of recycled elements.
- Transport distances are marginally important, whereas machine operation for deconstruction has a significant influence on EI.
- The combination of reuse and new elements leads to structures of least EI.

Further information can be accessed at: *gennarosenatore.com/research/design_of_structures_through_reuse*

Innovative Teaching Practices

Courses

I have contributed to advancing innovative teaching practices through the development and delivery of three interdisciplinary and methodologically forward-looking courses. **Ultralightweight Construction** introduces a novel approach to structural design as an inverse problem, equipping students with state-of-the-art computational tools to design resilient, low-carbon systems capable of efficiently counteracting the effects of loads through the use of sensors, actuators, and active control strategies. **Digital Design** empowers students to structure the design process as a dynamic, data-driven workflow, combining parametric modeling and algorithmic thinking to navigate multi-objective scenarios in collaboration with diverse stakeholders across engineering domains. **Introduction to Scientific Writing** fosters critical research and communication skills through a structured, hands-on curriculum that guides students in transforming complex ideas into clear, impactful scientific texts. Together, these courses prepare students to engage with contemporary challenges in engineering and design through innovative and interdisciplinary practices.

Educational Tools

To foster **deeper engagement and broaden accessibility** in structural mechanics and computational design synthesis, I have developed active and game-based learning strategies by integrating computer graphics techniques with numerical methods for structural analysis [17]. This formulation underpins *PushMePullMe,* an interactive educational tool I developed to support the teaching of structural mechanics and conceptual structural design.

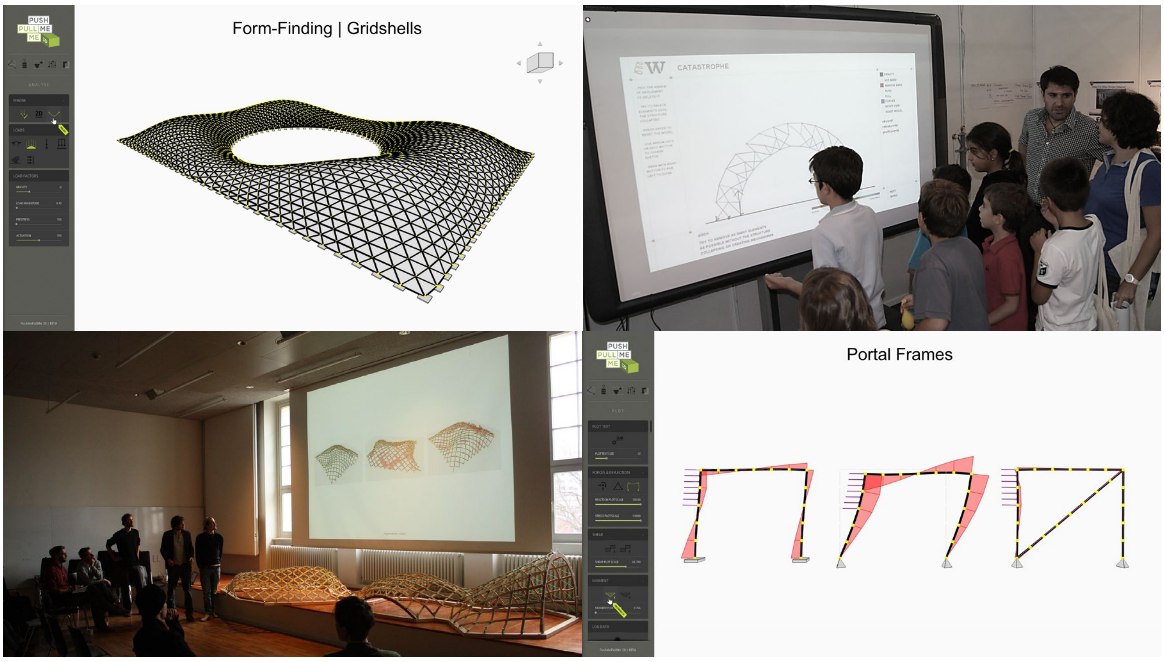

Figure 6 PushMePullMe *used in teaching: form-finding of gridshells (top left); primary-school outreach session (top right); student presentation and prototype of gridshell designs (bottom left); structural behavior visualization for portal frames (bottom right).*

The resulting formulation is a vector-based finite element method that combines the Dynamic Relaxation (DR) method with the Co-Rotational approach and large-rotation theory. This enables the simulation of arbitrarily large displacements, including rigid body motions and mechanisms and supports a wide range of structural configurations — reticular structures such as cable nets, trusses, frames, tensegrity systems, and deployables, as well as shells and solids. Since equilibrium is reached iteratively, both local and global buckling are inherently accounted for, allowing for interactive tasks such as shape and topology optimization. The software allows users to manipulate structural forms directly, pushing and pulling with a mouse or touch interface, while real-time feedback on deformations and stresses builds intuitive understanding of structural behavior. Designed for wide accessibility, *PushMePullMe* has been used in public workshops with participants of all ages and backgrounds, and is embedded in both secondary and tertiary education curricula. Assessments show its strong potential to **improve student engagement and promote diversity and inclusion in STEM education**.

Further information can be accessed at: *gennarosenatore.com/teaching*

Knowledge Transfer and Societal Impact

I have served as **Lead Expert** for **Emerging Technologies** in a Preparatory Action for the **New European Bauhaus** (NEB), appointed by the Joint Research Centre (JRC) of the European Commission. Over the course of this two-year appointment, I have collaborated with experts across Europe to streamline and consolidate knowledge frameworks — including standards, codes of practice, and guidelines. This work has resulted in the *NEB Self-Assessment Method*, a first-of-its-kind, holistic, and multi-dimensional guideline for the built environment [18]. It synthesizes harmonized performance indicators across sustainability, functionality, aesthetics, emerging technologies, inclusiveness, governance, and economy. These indicators have been operationalized through an accessible, **transdisciplinary** self-assessment framework, achieving both **methodological innovation** and **high-impact knowledge transfer**. The resulting tools directly support the policy objectives of the European Green Deal and enable stakeholders to align their projects with NEB values, thereby enhancing access to funding and promoting the broader adoption of climate-neutral, inclusive, and culturally enriching practices in the built environment.

Further information can be accessed at: *knowledge-management.new-european-bauhaus.europa.eu*

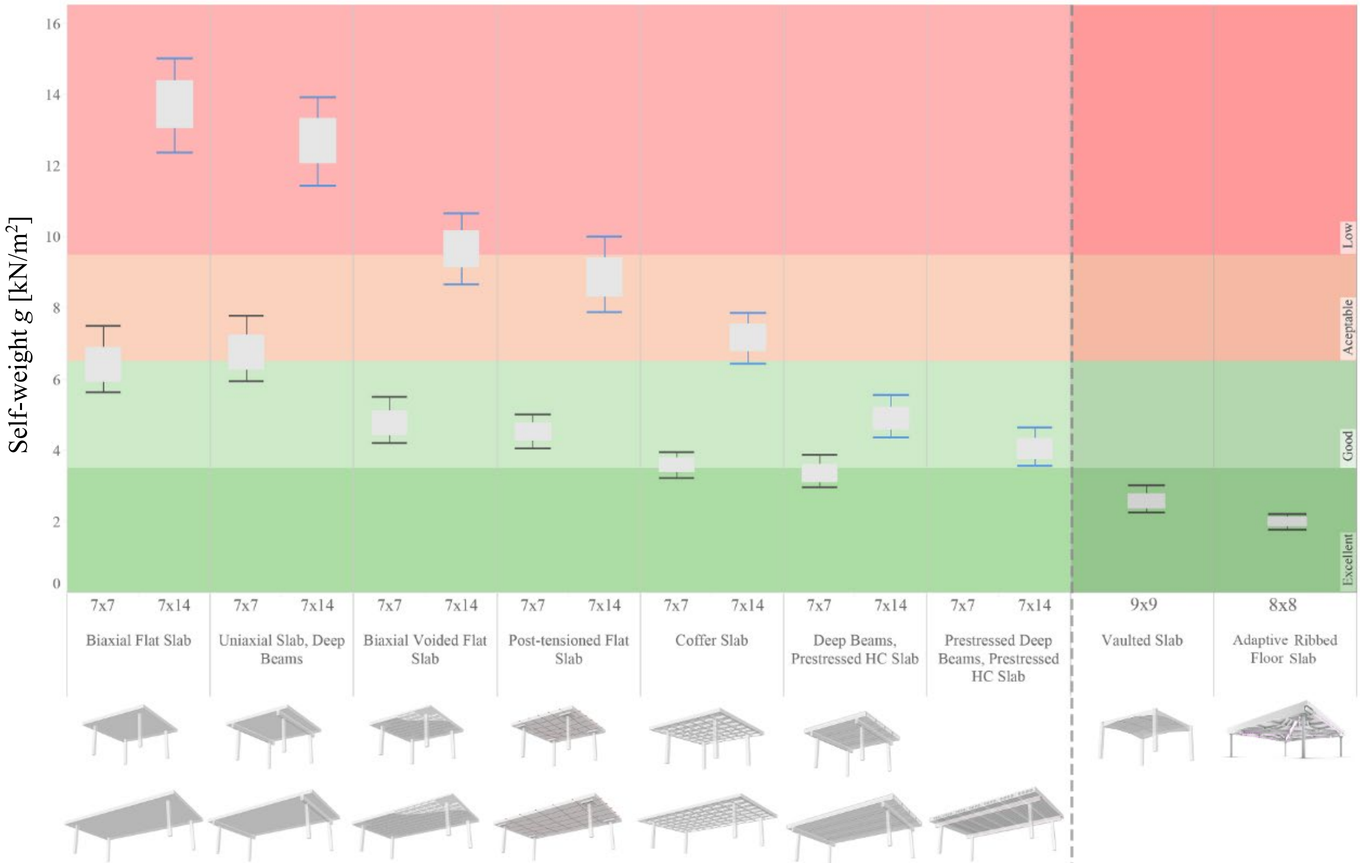

Figure 7 Structural resource intensity indicator for concrete slabs [18]; The dashed line marks the threshold attainable with emerging technologies, including vaulted and adaptive rib-stiffened slab systems.

Academic Vision

These efforts demonstrate a coherent academic trajectory that integrates research, education, practice, and knowledge transfer. Through the development of pioneering methods for adaptive structural systems, the advancement of interdisciplinary and computationally enriched teaching practices, and contributions to international policy frameworks such as the New European Bauhaus, **this body of work bridges fundamental science and societal impact**. By cultivating an inclusive and globally connected research environment, I seek to train the next generation of engineers and designers to extend the boundaries of knowledge while addressing urgent global challenges.

Looking ahead, my vision is to consolidate this integration by linking computational design synthesis innovations across material scales and disciplinary domains into scalable frameworks that **push structural performance beyond conventional limits**, enabling the next generation of intelligent and low-carbon structures and infrastructure for the built environment. In doing so, I aim to reimagine load-bearing structures as multifunctional, **coupled physical–digital agents** that **achieve more with less material and energy**, enhance resilience, reduce environmental impact, and enrich human experience, thereby reshaping the built environment to serve both people and planet.

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Research Output

Gennaro Senatore

Peer-reviewed Scientific Articles

The 10 most important publications are highlighted.

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[59] **G. Senatore**, Q. Wang, H. Bier and P. M. Teuffel, "The use of variable stiffness joints in adaptive structures," in *Proceedings of the Annual Symposium of the International Association of Shell and Spatial Structures (IASS)*, Hamburg, 2017.

[60] **G. Senatore**, P. Duffour and P. Winslow, "Adaptive Building Structures Two Case Studies," in *Proceedings of the Annual Symposium of the International Association of Shell and Spatial Structures (IASS)*, Tokyo, Japan, 2016.

[61] **G. Senatore**, P. Winslow, P. Duffour and C. Wise, "Infinite stiffness structures via active control," in *Proceedings of the Annual Symposium of the International Association of Shell and Spatial Structures (IASS)*, Amsterdam, Holland, 2015.

[62] **G. Senatore**, P. Duffour, P. Winslow, S. Hanna and C. Wise, "Designing adaptive structures for whole life energy savings," in *Proceedings of the Fifth International Conference on Structural Engineering, Mechanics & Computation, Cape Town*, South Africa, 2013.

[63] **G. Senatore**, P. Duffour, P. Winslow, S. Hanna and C. Wise, "Exploring the domain of application of adaptive structures," in *Proceedings of the Fifth International Conference on Structural Engineering, Mechanics & Computation, Cape Town*, South Africa, 2013.

[64] E. McCann, **G. Senatore** and A. Crowther, "Expedition Workshed: Engineering education for the 21st century," in *Proceedings of the International Association for Bridge and Structural Engineering - International Association of Shell and Spatial Structures Symposium* 2012, London, UK, 2012.

[65] **G. Senatore**, P. Duffour, S. Hanna and F. Labbe, "Pumping vs. Iron. Adaptive Structures for whole life energy savings," in *International Conference on Intelligent Environments*, Nottingham, UK, 2011.

Contribution to Books

[66] Joint Research Centre (European Commission), P.B. Lourenço, T. Maloutas, M. Santamouris, B. Widera, F. Ansaloni, C. Balaras, I. Katurić, D. Kolokotsa, T. Rossetto, **G. Senatore**, A. Tomaszewicz, E. Medeiros, K. Gkatzogias, D. Pohoryles, E. Romano et al., "A practical guide to the New European Bauhaus self-assessment method and tool", *Publications Office of the European Union*, 2024, doi: 10.2760/9581060

[67] **G. Senatore**, "Designing and Prototyping Adaptive Structures - an Energy-based Approach beyond Lightweight Design," in *Robotic Building*, H. Bier, Ed., Dordrecht, Springer, 2018, pp. 169-189, doi: 10.1007/978-3-319-70866-9_8

Oral Contribution to Conferences (Keynotes)

[68] **G. Senatore**, "Recent Advances in the Design of Adaptive Structures: from Structural Control toward Intelligent Structural Synthesis", *xArch Symposium*, Xi'an Jiaotong-Liverpool University, 2026.

[69] **G. Senatore**, "Force-serial and Force-parallel Actuation Placement for Topology Optimization of Adaptive Structures," International Association for Shell and Spatial Structures, Zurich, 2024.

[70] Presentation of paper [44], 14th World Congress in Computational Mechanics, Paris, 2021.

[71] Opening statement and presentation of paper [47] at mini-symposium *Adaptive Structures: Design, Optimization and Control* at the 7th International Conference on Structural Engineering, Mechanics and Computation, Cape Town, South Africa, 09/2019.

[72] **G. Senatore**, "Synthesis and Testing of Minimum Energy Adaptive Structures", *Multiscale Innovative Materials and Structures* (MIMS), Salerno, 2019.

[73] **G. Senatore**, "Design and Control of Minimum Energy Adaptive Structures", *Italian Association of Theoretical and Applied Mechanics* (AIMETA), Rome, 2019.

[74] **G. Senatore**, Y. Wang, J. Brutting, "Minimum Energy Adaptive Structures – All-In-One Problem Implementation", *International Association for Shell and Spatial Structures* (IASS), Barcelona, 2019.

[75] **G. Senatore** and I. F. C. Smith, "Design and Control of Adaptive Civil Structures," in Henderson Colloquium, International Association for Bridge and Structural Engineering (IABSE), Cambridge, UK, 2018.

[76] **G. Senatore**, "Optimal Actuator Layout for Adaptive Structures under Quasi-Static Loading," in World Congress of Computational Mechanics, New York, US, 2018.

[77] Plenary session presentation of paper [53], International Association of Shell and Spatial Structures (IASS), Boston, US, 2018.

[78] Presentation of paper [57], 7th German Association for Computational Mechanics, Stuttgart, Germany, 2017.

[79] **G. Senatore**, "Adaptive Building Structures" at Future of Design, International Association for Bridge and Structural Engineering, Bristol, UK, 2016.

[80] Plenary session presentation of paper [35], International Association of Shell and Spatial Structures (IASS), London, UK, 2011.

[81] **G. Senatore**, "Responsive Building Structures", PhD Symposium – Digital Relations in Architecture, Copenhagen, 2010.

Educational Tools (Software)

[82] *PushMePullMe* – Interactive educational software for teaching structural mechanics and form finding. Enables real-time manipulation of structural systems to foster intuitive understanding of load-response behavior. Used in university courses, public workshops, and STEM outreach programs internationally.

[83] *Make A Scape* – Game-based learning tool that introduces core principles of structural engineering through an accessible, scenario-driven interface. Developed for use in secondary and tertiary education, as well as public exhibitions.

Outreach

Exhibitions

[84] École polytechnique fédérale de Lausanne (EPFL) open house 2019. Lausanne, Switzerland, 09/2019. https://www.gennarosenatore.com/exhibitions/epfl-open-house-2019.html

[85] Permanent exhibit at *Institute for Lightweight Structures and Conceptual Design,* University of Stuttgart, since 10/2018. https://www.gennarosenatore.com/exhibitions/ilek.html

[86] Exhibition (one month) at *The Building Centre,* London, UK, 09/2016 https://www.buildingcentre.co.uk/whats_on/exhibitions/adaptive-structures2016-08-02

[87] Exhibition (one week) at *International Association for Shell and Spatial Structures*. Amsterdam, Holland, 05/2015 https://www.gennarosenatore.com/exhibitions/iass_amsterdam.html

[88] Exhibition (one week) at *University College London*. London, UK, 05/2015 http://www.gennarosenatore.com/exhibitions/ucl_truss_launch.html

Invited lectures (selected)

[89] Zhejiang University, College of Civil Engineering and Architecture, Hangzhou, China, 03/2026

[90] Aarhus University, Department of Civil and Architectural Engineering, Aarhus, Denmark, 01/05/2025

[91] Iowa State University, Architecture and Design Studies, Ames, US, 22/02/2023

[92] University of Stuttgart, Institute for Lightweight Structures and Conceptual Design (ILEK), Stuttgart, Germany, 15/09/2021

[93] Cambridge University, Department of Civil Engineering, Cambridge, UK, 09/10/2020

[94] Columbia University, Department of Civil Engineering and Engineering Mechanics, New York City, US, 21/01/2020
[95] Federico II University, Department of Structures for Engineering and Architecture, Naples, Italy, 08/11/2019
[96] University of Salerno, Department of Civil Engineering, Salerno, Italy, 08/11/2019
[97] California Institute of Technology, Department of Aerospace, Pasadena, US, 12/10/2018
[98] Oak Ridge National Laboratory, Manufacturing Demonstration Facility, Knoxville, Tennessee, US, 31/07/2018
[99] University of Stuttgart, Institute of Lightweight Structures and Conceptual Design, Stuttgart, Germany, 23/11/2017
[100] Swiss Federal Institute of Technology (EPFL), Smart Living Lab, Fribourg, Switzerland, 03/10/2017
[101] The Institution of Structural Engineers (IStructE), London, UK, 23/06/2017
[102] Eindhoven University of Technology, Chair of Innovative Structural Engineering, Eindhoven, Holland, 11/05/2017
[103] Delft University of Technology, Faculty of Architecture and Built Environment, Delft, Holland, 12/05/2017
[104] Sheffield University, School of Architecture, Sheffield, UK, 17/11/2016
[105] Sheffield University, Department of Structural Engineering, Sheffield, UK, 16/11/2016
[106] Cambridge University, Department of Civil Engineering, Cambridge, UK, 28/10/2016
[107] PLP Architecture, London, UK, 25/10/2016
[108] Buro Happold Engineering, London, UK, 13/09/2016
[109] Design Computing Community, London, UK, 04/02/2016
[110] Imperial College London, Department of Civil and Environmental Engineering, London, UK, 21/09/2015
[111] Vision 2015, London, UK, 08/06/2015
[112] Hopkins Architects, London, UK, 02/2015
[113] Future Tech Forum, London, UK, 15/09/2015
[114] Swiss Federal Institute of Technology (EPFL), Institute of Civil Engineering, Lausanne, Switzerland, 30/10/2015
[115] University of the Arts, Berlin, Germany, 27/11/2014
[116] University College London, Bartlett School of Architecture, London, UK, 14/11/2012

Interviews

[117] Gennaro Senatore, Ian Smith and Arka Reksowardojo "Adaptive structures cut down the carbon footprint of buildings" *https://actu.epfl.ch/news/adaptive-structures-cut-down-the-carbon-footprint*

[118] Gennaro Senatore and Chris Wise on theory and application of adaptive structures *https://vimeo.com/gennarosenatore/adaptivestructures*

[119] Keep It Civil 201 - *https://soundcloud.com/cege_ucl/keep-it-civil-201-adaptive-building-structures*

Press

[120] "Structural strength when you need it", *Innovation & Research FOCUS* (Institution of Civil Engineers), vol. 102, August 2015 *http://www.innovationresearchfocus.org.uk/Issues/102/IRF102_ICE.html*

[121] "Supertall, super-smart | Adaptive structures", *New Civil Engineer,* September 2016 *https://www.newcivilengineer.com/archive/super-tall-super-smart-adaptive-structures-09-09-2016/*

[122] "Adaptive structures", *Design Buildings Wiki* *https://www.designingbuildings.co.uk/wiki/Adaptive_structures*

[123] "This week's picks for London architecture and design events", *Archinect News* *https://archinect.com/news/article/149963347/this-week-s-picks-for-london-architecture-and-design-events*