University of Pennsylvania
STUART WEITZMAN SCHOOL OF DESIGN
Department of Architecture

Material and Structural Intelligence
ARCH 732-002 | Fall 2022

Instructors: **Sameer Kumar** *(kumars2@upenn.edu)*

Class Meetings: **Fridays; 8:30 am - 11:30 am EST**
Location: **TBA**

Course Description:
Founded on a materialist ontology, *Material and Structural Intelligence* will explore the genesis of architectural form as informed by natural forces and material behavior. The course aims to utilize methods of thinking and making that are informed by these inherent forces and which would allow for the emergence of formal solutions that are inherently in equilibrium with their context and nature. The course relies on building sophisticated digital and physical models that parameterize real world metrics related to structural behavior and material performance.

The process of formation, analysis, and refinement developed through the course will expose the students to the relationship between form, structure, and materials with an emphasis on efficiency and functionalism. The readings and research component of the course would help define the historical context within which the ideas of lightweightedness, hyper efficiency and minimalism have underpinned the conversation around ecological sustainability within architecture since the middle of twentieth century.

This line of inquiry is also rooted in a deep tradition at PennDesign designers and academics such as Louis Kahn, Le Ricolais, Peter McCleary, Detlef Mertins, and Cecil Balmond have shaped how we think about the poetics, capabilities and possible futures at the heart of the intersection of material behavior, structural performance and morphogenesis.

Our focus is on exploring this synergistic relationship through hands on experimentation with structurally active models and the development of dynamic, iterative, digital simulations. Through close interaction and discussion with visiting designers, artists, and engineers, this course will broaden students' understanding of the intersection between design, engineering, and material creation.

The design component of the seminar will begin with the exploration of fundamental structural and material principles through the creation of abstract structurally active models. Students might explore such principles as flexure, anticlastic curvature, tension, thrust, etc. Those studies will be refined and enriched through iteration, digital simulation, and critical analysis. As part of this exploration, students will research relevant material systems. Ultimately, working with teams, students will prepare an architectural proposal which applies the fundamental principles developed through this investigation.

Lectures will be given by the instructors and invited guests throughout the semester to develop a basis of knowledge on the history, current state and future trajectory of basic material and structural systems such as concrete, wood, and metal as well as less common systems such as fabrics, glass, and composites. Students will also participate in building this common basis of knowledge through the research and presentation of historical innovators that have been instrumental in advancing the discipline.

Goals/Learning Objectives:

- To understand the historical lineage of lightweight architecture and other approaches towards more sustainable structures
- To learn to design optimized, lightweight architectural forms shaped by structural performance and informed by material behavior
- Explore a design process that employs physical and digital tools to discover optimized forms

Format:

The semester has been framed into three phases as described below. Reading assignments will be given most weeks to coincide with upcoming lectures and precedent presentations. Class may include lectures, discussions of readings, digital pinups, presentations by guest lecturers and work-sessions with core instructors.

The course will challenge students to develop physical, digital, and graphic tools to communicate complex ideas about form, structure and materiality. Special emphasis is given to the use of graphic representation, model making, simulation, and technical documentation as analytical tools.

Part 1 | Research

Build a collective understanding about fundamental structural principles and material properties through presentations, discussion, precedent research, and experimentation.

Part 2 | Concept Design

Using the principles unearthed through research, students will develop an architectural concept that is innovative, potent, rational, and lightweight. Continue to explore though digital and physical models.

Part 3 | Development and Documentation

Build a structurally active model of a well developed architectural proposal. Continue to advance the design through documentation. The students will develop a set of drawings which beautifully and intelligibly describe their design intent and proposed building systems.

Schedule and Deliverables:

Week	Date	Agenda	For Next Week
1.1	9/2	**Introduction** Lecture 1: The history and possible futures of material and structural systems Discuss syllabus, deliverables, precedent project types, introduce instructors. Assign Precedents	**Produce -** Identify structural modules or systems within the body of work of your assigned precedent for further investigation as a case study.
1.2	9/9	**Form & Forces** Lecture 2: Exploring fundamental principles of form and forces and how it can shape structures. Students share examples	**Produce** Develop a structurally active model based on knowledge of fundamental structural principles.
1.3	9/16	**Form & Material** Lecture 3: Architectural form as a representation of the evolving state of knowledge and technology Review Student Work	**Produce** Refine analysis and structurally active model
1.4	9/23	**Materiality & Structure** Lecture 4: Traditional and novel building materials and composites and their use in lightweight structures **Digital Workshop (off hours)** Introduce tools and techniques in Rhino/GH	**Produce -** Build a dynamic digital model
1.5	9/30	**Phase 1 Wrap Up Review** Guest Lecture (TBD) Group Assignment	**Read-** Reading A **Prepare-** Precedent Presentation 1

	10/7	**No Class** (Studio Travel Week)	
2.1	10/14	**Phase 2 Kickoff / Introduce Site** Review Student Work Precedent Presentation 1 Discuss Reading A	**Read-** - **Prepare-** - **Produce-** Options for Site and Program
2.2	10/21	**Introduce Program** Review Student Work Guest Presentation: ICD Stuttgart	**Read-** Reading B **Prepare-** Precedent Presentation 2 **Produce-** Digital models for proposal of integration into the site
2.3	10/28	**Introduce Material** Review Student Work Precedent Presentation 2 Discuss Reading B	**Read-** Reading C **Prepare-** Precedent Presentation 3 **Produce** Adjustment of proposed structure based on program
2.4	11/4	**Materiality and Structure** Review Student Work Precedent Presentation 3 Discuss Reading C	**Read-** Reading D **Prepare-** Precedent Presentation 4 **Produce -** Drawings and Models for review
2.5	11/11	**Phase 2 Wrap Up Review** Guest Lecture (TBD) Precedent Presentation 4 Discuss Reading D	**Read-** Reading F **Prepare-** Precedent Presentation 6 **Produce -** Finalize Concept Design

3.1	11/18	**Drawing & Detailing** Discussion on methods of accurately, beautifully, and informatively drawing complex geometry Precedent Presentation 5 Discuss Reading E	**Produce -** Develop a plan for the final phase
3.2	11/23 (Wed)	**Assemblies and Sequence** Discussion on methods of execution and assembly and the impact of construction sequence on the architecture Precedent Presentation 6 Discuss Reading F	**Produce -** Identify key details, drawings, diagrams
3.3	12/2	**Working Session** Review Student Work Guest Lecture	**Produce -** Set up clear scope for large scale structurally active final model
3.4	12/9	**Working Session (optional)** Review Student Work	**Produce -** Finalize Development and Documentation
3.5	12/16	**Final Review**	

About the Instructors:

Sameer Kumar AIA | Director of Enclosure Design at SHoP Architects

Sameer is a practicing architect and a specialist in the design of building enclosures. He has degrees in architecture from University of Pennsylvania and CEPT, Ahmedabad. In addition to leading the facade design effort on all the current projects at SHoP Architects, he also teaches at University of Pennsylvania and Princeton University.

Florian Meier PE | Associate Director, Knippers Helbig

Florian is an Associate Director with Knippers Helbig and is leading the New York Office. He was trained at the Technical University of Munich, with a focus on computational formfinding methods and structural optimization, and has experience in a variety of materials and structural typologies. He also teaches at the Architecture program at The Cooper Union.

Method of Assessment:

Students will work both individually and in groups, and will be evaluated accordingly. Student work will be evaluated throughout the semester based on the following criteria:

Phase 1 (Group)	20%
Research	
Phase 2 (Group)	30%
Material Understanding/Innovation	
Structural Understanding/Innovation	
Phase 3 (Group)	40%
Final Models	
Final Drawings	
Design	
Class Participation	10%

During class times attendance is mandatory and students are encouraged to learn from the reviews of their peers as much as from your own. More than two unexcused missed attendances will result in exclusion from the class.

Academic Integrity
Academic honesty is fundamental to our scholarly community. The Pennbook contains the University Code of Academic Integrity, to which the School of Design strictly adheres. A confirmed violation of that Code in this course will result in a failing grade, and likely in other disciplinary measures. The UPenn Code of Integrity is available online at: https://catalog.upenn.edu/pennbook/code-of-academic-integrity/.

Precedent Research and Related Readings:

- Viollet-Le-Duc & Antoni Gaudí
    - Antoine Picon: “The first steps of construction in iron” in Before Steel
    - R. Graefe: “The legendary model of Colònia Güell built by Antoni Gaudí” in B. Addis “Physical Models”
- Frei Otto & Ted Happold
    - Excerpt from Finding Form | Arches, Vaults, Shells
    - Excerpt from Martin Bechtold | Form-finding & analysis
    - Delanda from NOX
- Buckminster Fuller & Le Ricolais
    - Things Themselves are Lying
    - Bioconstructivisms
    - On The Theory of Transformations
- Heinz Isler & Felix Candela
    - Excerpt from The New Structuralism | Form-Finding in Design
    - Excerpt from Martin Bechtold | Form and Structure
    - Excerpt from Martin Bechtold | The Quest for Thinness
- Peter Rice & Richard Rodgers / Renzo Piano
    - P. Rice “An Engineer Imagines”
- Kisho Kurokawa, Cedric Price & Archigram

- Achim Menges / Jan Knippers & Gramazio + Kohler
    - Excerpt from Material Computation | Material Behavior
    - Excerpt from Digital Fabrication: A. Menges - Coalescences of Machine and Material Computation
    - Sanford Kwinter | Who's Afraid of Formalism
    - Fabio Gramazio, Matthias Kohler: "Authoring Robotic Processes" in "AD Made by Robots"
- Eladio Dieste & Phillipe Block
    - J. Ochsendorf: "Eladio Dieste as Structural Artist" in "Eldio Dieste - Innovation in Structural Art"
    - E. Allen: "Guastavino, Dieste, and the two revolutions in masonry vaulting" in "Eldio Dieste - Innovation in Structural Art"
- Cecil Balmond & Toyo Ito
    - Excerpt from The Informal
    - Excerpt from Digital Culture in Architecture | The Seduction of Innovative Geometries
- Jorg Schlaich & Kawaguchi Mamoru
    - M. Schlaich: " Kawaguchi Mamoru" in "Structured Lineages: Learning from Japanese Structural Design"
    - Excerpt from The New Structuralism
    - Suitable Shell Shapes
- Naum Gabo & Vladimir Shukhov
    - Excerpt from M. Beckh: "Hyperbolic Structures: Shukhov's Lattice Towers - Forerunners of Modern Lightweight Construction"

Informing Texts:

- AD | March/April 2012 | Material Computation | Edited by Achim Menges
- Philip Ball | Nature's Patterns: a tapestry in three parts | Shapes, Branches, Flow
- Martin Bechthold | Innovative Surface Structures: Technologies and Applications
- Paul Jackson | Folding Techniques for Designers
- Manuel Delanda | Philosophy and Simulation
- Sanford Kwinter | Who's Afraid of Formalism
- Detlef Mertins | Bioconstructivism
- Frei Otto | Finding Form
- Jesse Reiser | Atlas of Novel Tectonics
- The Tell-the-Tale Detail | Marco Frascari
- Cecil Balmond | The Informal
- AD | July/August 2010 | The New Structuralism | Edited by Rivka Oxman and Robert Oxman