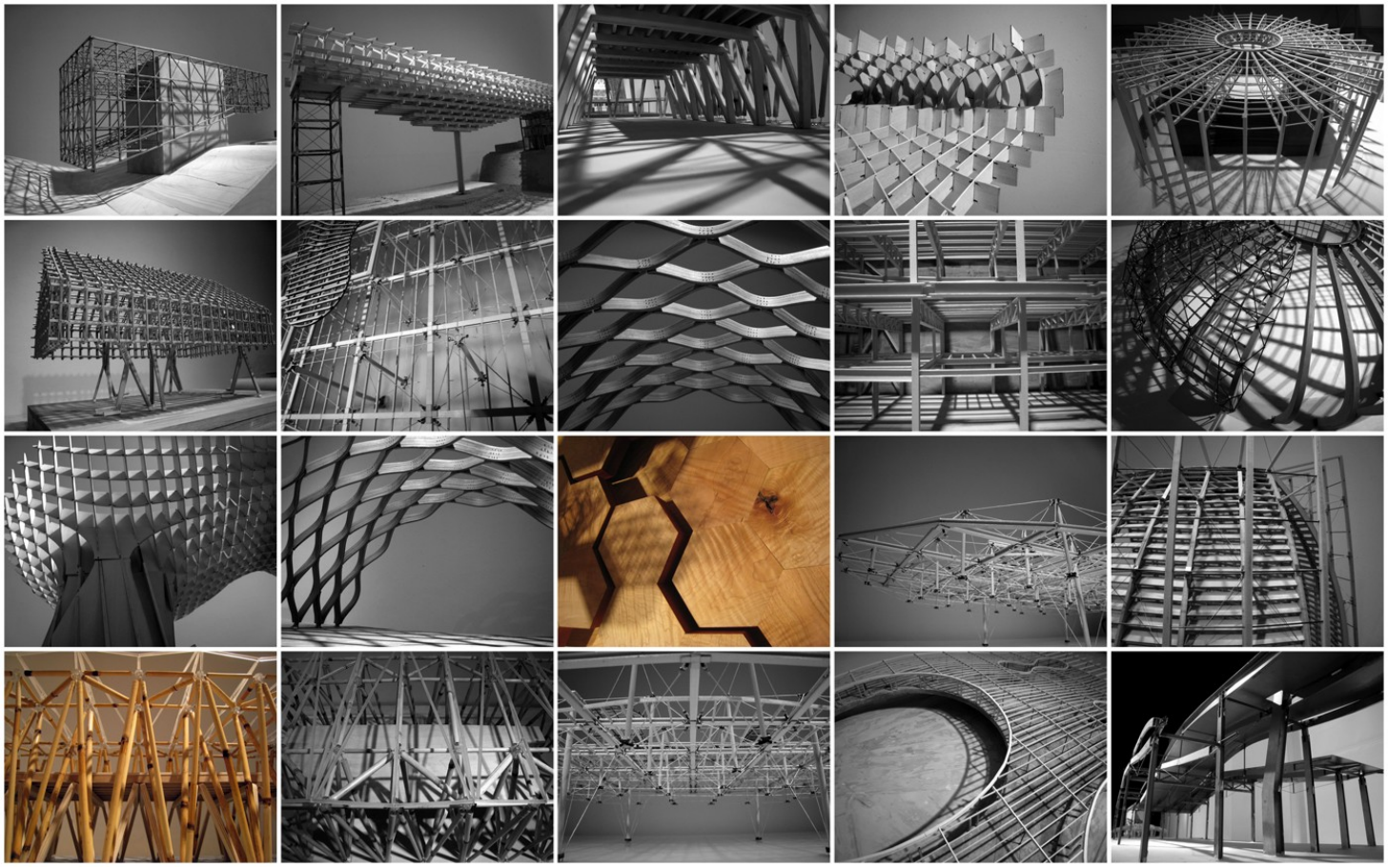
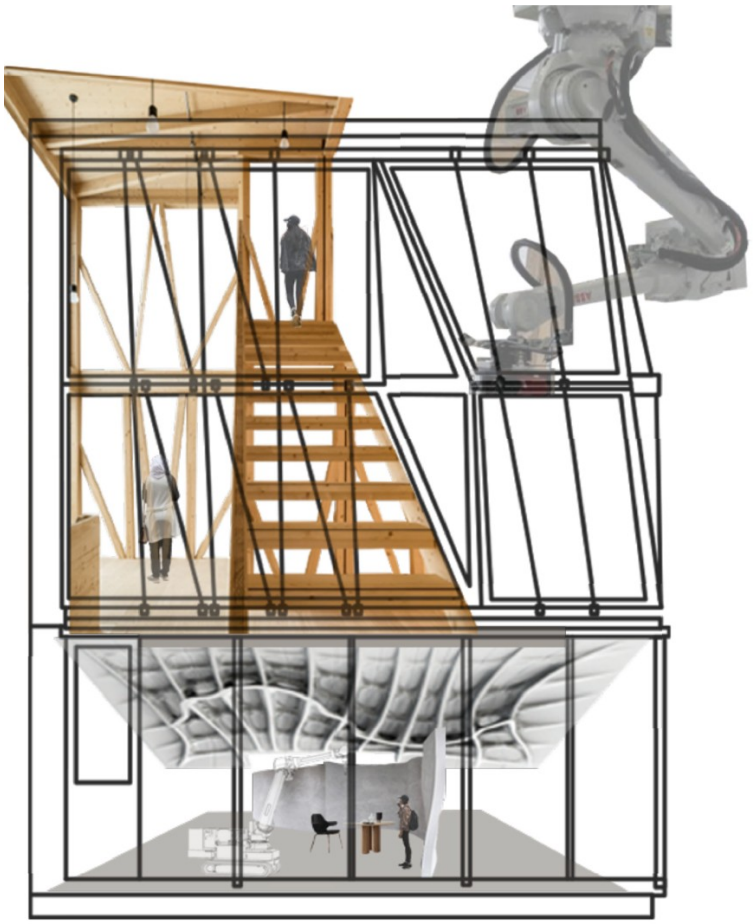
ARCH 2613 / 5613 Structural Systems

Prof. Mark Cruvellier **Fall 2023**
Milstein Hall Auditorium; Tuesdays 8:30-11:00am; Modality: In-person only

Grading/credits: Required course for both B.Arch & M.Arch students;
Letter grading; 3 credits

Instructor office, email: 340C E.Sibley Hall, mrc14@cornel.edu
Office Hours: Thursdays [or Tuesdays (day & time to be confirmed) 1:00-2:30 pm
TA sessions: Required weekly consultation sessions as scheduled by the TAs:
Seth Brayton (MArch thesis), Alexandra Ciobanu (BArch 5th year)
Dana Herrault (MArch thesis), Gabby Melton (BArch 4th year)
Sally Tang (BArch 3rd year), Weiqi Wang (MArch thesis)





The name "DFAB" beckons to the familiar term, "Prefab", and we are pleased to inform you that this is an intentional nod. The DFAB house was prefabricated, but more importantly, it was (D)igitally prefabricated. In other words, genius robots were involved in the architecture's actualization. This is not the first example of an architecture fabricated with the help of robots, however, it is the first of its kind to include all six of these new building technologies:

The In situ Fabricator
a versatile autonomous on-site construction robot

Mesh Mould
a formwork-free, robotic process for steel-reinforced concrete structures

Smart Dynamic Casting
an automated concrete slip-forming process

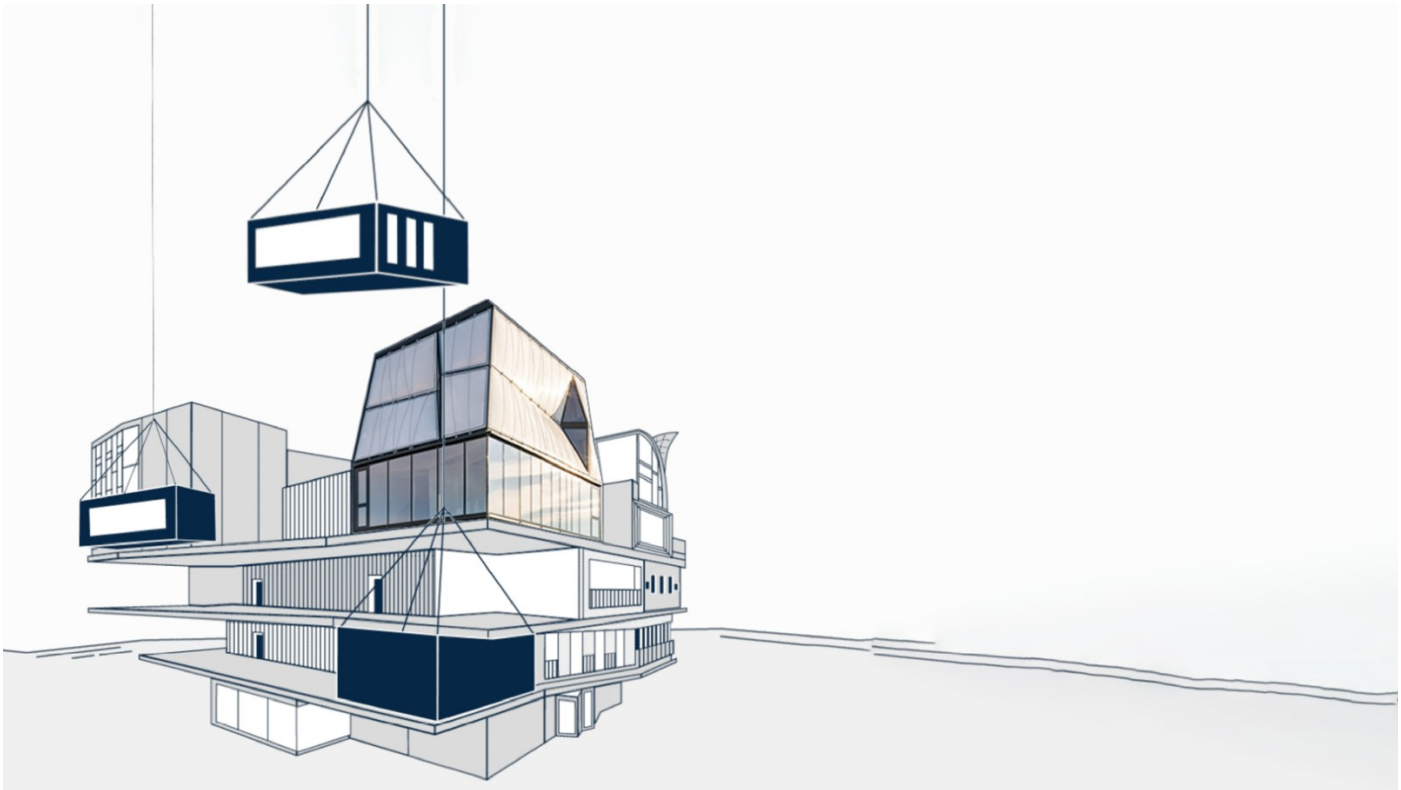
Smart Slab
integrated ceiling slabs fabricated with 3D-printed formwork

Spatial Timber Assemblies
a robotically fabricated timber structure

Structure need not be complex in form. In the case of the DFAB House, complexity is found elsewhere: in the fabrication process.

DFAB HOUSE
AN AMALGAM OF PROCESSES | WALKTHROUGH

GROUP 12 | ADDIE REINE & MITCHELL CARSON



Architects | NCCR Digital Fabrication & ETH Zurich
Location | Dübendorf, Switzerland
Area | 2,150 ft2
Year | 2019

DFAB HOUSE
INTRODUCING | WALKTHROUGH

GROUP 12 | ADDIE REINE & MITCHELL CARSON

ARCH 2613 / 5613 Structural Systems

Prof. Mark Cruvellier **Fall 2023**

TAs: Seth Brayton, Alexandra Ciobanu, Dana Herrault, Gabby Melton, Sally Tang, Weiqi Wang

I. Rationale for the Course:

Understanding how building structural systems are configured and how they work to carry lateral and gravity loads is fundamental to becoming an architect. With such an understanding comes the ability to collaborate with other design professionals to inform the design of a building's overall form and internal spaces and to develop a structural system that is in keeping with overall conceptual ideas and objectives.

II. Course Aims and Objectives:

Overall 3D structural systems that are used in buildings are closely examined in this course – i.e., braced frames, rigid frames and shear wall systems are vertical subsystems for resisting lateral loads, while other structural systems are configured primarily to span space horizontally and to transfer gravity loads between vertical supports, including stayed and suspension cable systems; cable nets and fabric membranes; arches, vaults and domes; slabs, folded plates and curvilinear shells; beam systems and truss form equivalents and as well as other particular systems such as diagrids and reciprocal frames, space frames and tensegrity systems, etc., etc. As we shall see, this subdivision is often not so clear-cut; in reality, structural systems often share their load-carrying responsibilities.

The simultaneous objectives of the course are both to develop an understanding how these systems "work" in terms of their mechanical functioning but also how they can be related to conceptual design ideas as well as external formal intensions and space-making objectives. The material in this course is primarily approached in a qualitative and discursive manner, and is illustrated by a broad range of examples, both historical and (especially) by contemporary built projects. In addition, relatively accessible mathematical equations and calculations are used to reinforce and extend a fundamental understanding and appreciation for these systems' essential characteristics and possibilities. Particular focus is placed on the structural systems that resist lateral loads on buildings and that span significant distances to create inhabitable/occupiable spaces, as well as on how such systems interact with each other to become one cohesive structural/spatial/conceptual entity.

III. Format and Procedures:

The course format and requirements are structured into two main parts: 1) an abbreviated but nevertheless conceptually complete set of weekly summarizing notes by the student on the assigned readings, complemented by a few selectively annotated key drawings and photos of the projects shown in class lectures as well as some thoughtful reflections on related text passages as assigned (all parts of these weekly assignments are to be done individually, and are be the student's original work) and 2) the completion of a highly detailed & semester-long research investigation of the structural system a completed contemporary building of your choosing. This project is to highlight and illustrate the overall 3D structural system's form and to include details that reflect and interpret the working of its structural system and culminate in either a physical model (for B.Arch / ARCH 2613 students working in groups of three) or else in a highly and creatively detailed illustrated walkthrough project (done by pairs of M.Arch / ARCH 5613 students), with the option available upon request to do a physical model instead. Regular meetings for each group will be scheduled weekly and these must be attended in a participatory manner by all members of each group with their assigned TA. For more details of this project, see the detailed description provided separately.

IV. Instructor's Assumptions

The study of structural systems' form and behavior is of long-standing relevance and importance in the design of buildings, whether to ensure that these can safely withstand the gravity and lateral loads that are applied to them or because of how these systems' configurations can influence how a building looks and is occupied. The examples presented cover a broad range of material types and time periods and architectural design styles/concepts so as to ensure students' comprehensive knowledge of the topic; however, the lecture presentations and the projects undertaken also include and even emphasize the design of innovative building structural systems that have been developed within the context of contemporary architectural design concepts and building technology innovations of the past 25 years.

V. Course Requirements

1. Overall grading scheme:

- 40% Class Attendance & Engagement (including personal/original Reading and Lecture Notes, Annotated Images/Diagrams, and 1-2 paragraph Reading Reflections)

- 60% Structural System Physical Model Project (for B.Arch students done in groups of 3) or Illustrated Virtual Walk-through Project (for M.Arch student pairs – although this can instead be the Physical Model Project for those M.Arch students who feel that they would benefit from the experience of such project work)

See more details about the course requirements and grading policy in Section VI below.

2. Course materials:

- The required textbooks are the same as for last semester's ARCH 1612/5612 Structural Concepts course. Readings from these books will be assigned each week.

  The Structural Basis of Architecture, 3rd ed.; Sandaker, Eggen, & Cruvellier; Routledge, 2019; ISBN: 9781138651999

  Model Perspectives: Structure, Architecture & Culture; Cruvellier, Sandaker, & Dimcheff; Routledge, 2017; ISBN: 9780415731942

- Various other relevant materials for each lecture/topic will also be made available each week via Canvas; these will supplement and complement the content of the lectures and of the assigned readings. A comprehensive set of class notes and a few key annotated images (of selected photos and drawings) should be done during the class session; these are to be turned in along with the required reading reflections via Canvas and within 15 minutes of the end of class.

3. Course credits: The satisfactorily completed course will be assigned 3 academic credits.

4. Additional course requirements:

- Equipment needed for course (and estimated expenses): see details regarding model materials in separate project handout. The cost of materials and fabrication for the model construction should be carefully anticipated and budgeted in advance and is to be agreed upon and shared equally by all members of the group. While not precluded, many years of experience with this project have demonstrated that no benefit in terms of grading will be derived from the use of expensive materials and/or fabrication methods. Found and creatively used/reused materials are encouraged. That being said, it is also by no means the case that "anything goes"! The quality and amount of work

done for the finished model and its effectiveness in demonstrating the working of the structural system are critical considerations. Creativity, originality and effort will be highly rewarded.

- There are no expected travel expenses for this course.

VI. Grading Procedures:

Attendance for the full duration of each class is mandatory. The required notes & selected annotated images & reading reflection submission for each lecture will be checked by the TAs shortly after each class is over. Late submissions will not be graded. A maximum of up to two absences from class due to sickness or other university approved excuse will be permitted without penalty as long as advance notice is sent by the student to the instructor/TAs via email; beyond that, the penalty for each absence will be 7.5% of the final grade barring highly extenuating circumstances that must be approved by the instructor. A total of more than 4 unexcused absences will result in the atomatic failure of the course, notwithstanding how the student does on other aspects of the course.

Grades will be assigned based on performance on the two items and criteria listed below:

- 40% Class Attendance + summarizing Lecture & Assigned Reading Notes, including a few complementary Annotated Diagrams/Photos + a 1-2 paragraph Required Reading Reflection as assigned
  - hand-written/hand-drawn notes with annotated diagrams and assigned reading reflections are to be submit shortly after the end of each class session (these can be done manually and scanned or else produced digitally on a tablet); these submissions will be checked for overall clarity, completeness & engagement
  - an attestation is mandatory with each submission of reflections/notes/diagrams stating that these materials are soley the work of the student submitting them
  - late submissions of class notes, reflections, etc. will not be accepted without advance permission from the instructor/TAs and this will be granted only for acceptable University-specified reasons (e.g., illness, family emergency, religious holiday)
  - for each missing submission beyond two (2), a penalty of 7.5% of the final course grade will be assessed for each unexcused weekly submission that is missing
  - more than 5 missing or substantially incomplete sets of weekly reading reflections/lecture notes/image annotations will result in automatic failure of the course
  - a comprehensive and clearly organized collection of all of the weekly sets of notes, etc. for the semester is to be turned in before Thanksgiving Break; incomplete, disorganized, and/or poor overall quality of presentation of these materials will result in supplemental deductions

- 60% Structural System Model (B.Arch) or Illustrated Walk-through Project (M.Arch)
  - see separate handouts for details for these projects' submission requirements
  - the completion of a highly detailed & semester-long research investigation & structural system representation project for a contemporary building of your choosing that has been built within the past 10/15 years (pay close attention to the project limitations & restrictions) that includes the submission of a creative and well-executed physical model (these are to be done in groups of three B.Arch students or else an equally well-executed and creatively illustrated walk-through project (done in groups of two M.Arch students) that purposefully highlights the overall 3D structural system's form, materiality, key components and connection design details, site & context conditions, and that informatively interprets and represents the working of the structural system – all in a high quality & creatively detailed illustrated walk-through presentation
  - in both cases, the work will be graded for quality, originality, and evident effort and a single grade will be assigned for the group
  - the final submission of the project is due on the date indicated in the syllabus in mid-November; note that there are also interim submission deadlines and graded meetings with the assigned TAs throughout the semester that must be attended by all group members. Differences in grading within a group may result from notable differences in engagement and effort.

VII. Academic Integrity:

Each student in this course is expected to abide by the Cornell University Code of Academic Integrity. http://cuinfo.cornell.edu/Academic/AIC.html

Any work submitted by a student in this course for academic credit will be the student's own work, except in the case of projects that are specifically structured as group endeavors. Work that is done by others and shown in presentations and excerpted in papers must be properly cited and credited.

For this course, individual work is expected for the lecture notes, required reading reflections, and annotated diagrams whereas group work and collaboration is expected for the main project. Students can discuss information and concepts covered in the lectures to gain further clarity of the concepts, but these materials cannot be copied. Should copying occur, both the student who copied work from another student and the student who gave material to be copied will both automatically receive a zero for that work. The penalty for such violation of the Cornell Code of Academic Integrity can also be extended to include failure of the course and University disciplinary action.

Pursuant to ***Title 17 of the U.S. Copyright Act*** and **Cornell University Policy 4.15**, faculty own the copyright to all original course content – their copyright embodies course lectures as well as notes summarizing or capturing the lecture content. Students may take and use lecture notes solely for personal scholarship, and may share lecture notes only with others enrolled in the subject course. Students may ***not*** *post, copy, republish, distribute or share lecture, course, or class content in any form or medium* with anyone not enrolled in the subject course absent the express written permission of the faculty copyright holder. This prohibition applies to any platform or medium to which course lectures or notes are posted for the purpose of further distribution, whether for-profit or fee-free. Impermissible uses of copyrighted content constitute acts of copyright infringement and may further subject the student to violation(s) of the *Code of Academic Integrity*.

Student IP:

Students own the copyright to their work except under conditions specified in University Policy. The instructor and department may use students' copyrighted works in their teaching, lectures, etc., internal to the course. If the Instructor wishes to further display or distribute the work beyond Cornell's academic environment, the instructor will obtain of express permission from the student and provide appropriate attribution. Permission forms will be available in the College communications office.

Images of students:

For reasons including FERPA, DACA, and other privacy concerns, student permission is required before sharing photos or videos taken in studio, class, or on a field trip.

VIII. Diversity and Inclusion

Our Commitment:

We believe that design is a principal instrument of positive social change, and that progress and innovation are driven by a commitment to inclusion across race, class, ethnicity, gender, age, religion, ability and identity. For this reason, we explicitly confirm our resolute commitment to accelerate Cornell University's actions to be a diverse and inclusive institution. We embrace the responsibilities of ongoing internal critical reflection, dialogue, and action as individuals and as a community. We support the Cornell teaching community—our faculty, staff, and students—in their efforts to act with an ethos of inclusivism and antiracism in creating and sustaining diverse teaching and learning environments.

Bias-related Incident Reporting System:

Cornell University is committed to fostering a safe, respectful, and inclusive living, learning, and working environment for our entire community. The bias-related incident reporting system is one step toward promoting that we, as an institution, live out these values. The reporting system allows for you to safely and anonymously report an incident you may have experienced or witnessed, receive support, and explore options for resolution.

To report an incident, individuals can use one of the following methods:

- *By submitting an incident report online at https://www.biasconcerns.cornell.edu/ (non-emergency)*
- *By contacting the Cornell University Police Department (CUPD) at (607) 255-1111 or 911 for emergency assistance*

IX. Accommodations for Students with Disabilities

In compliance with the Cornell University policy and equal access laws, the instructor is available to discuss appropriate academic accommodations that may be required for students with disabilities. Requests for academic accommodations are to be made during the first three weeks of the semester, except for in unusual circumstances, so arrangements can be made. Students are encouraged to register with Student Disability Services [https://sds.cornell.edu] to verify their eligibility for appropriate accommodations.

X. Religious Holidays

Cornell University is committed to supporting students who wish to practice their religious beliefs. Students are advised to discuss religious absences with their instructors well in advance of the religious holiday so that arrangements for making up work can be resolved before the absence.

The New York State Legislature (since July 1, 1992) requires all institutions (public and private) of higher education not to discriminate against students for their religious beliefs. Accordingly, the pertinent parts of Sections 3 and 4 of the law state:

"3. It shall be the responsibility of the faculty and of the administrative officials of each institution of higher education to make available to each student who is absent from school, because of his or her religious beliefs, an equivalent opportunity to . . . make up any examination, study or work requirements which he or she may have missed because of such absence on any particular day or days…"

"4. If . . . classes, examinations, study or work requirements are held on Friday after four o'clock post meridian or on Saturday, similar or makeup classes, examinations, study or work requirements shall be made available on other days, where it is possible and practicable to do so."

A list of religious holidays can be found here:
https://scl.cornell.edu/religiousholidays

Land Acknowledgement:

The Department of Architecture acknowledges that Cornell University is located on the traditional homelands of the Gayogo̱hó:nǫ' (Cayuga Nation). The Gayogo̱hó:nǫ' are members of the Haudenosaunee Confederacy, an alliance of six sovereign Nations with a historic presence on this land. The Confederacy precedes the establishment of Cornell University, New York State, and the United States of America. We acknowledge the painful history of Gayogo̱hó:nǫ' dispossession, and honor the ongoing connection of Gayogo̱hó:nǫ' people, past, and present, to these lands and waters.

XI. Course Schedule:

Week Date Topic

1. 8/22 Course intro & overview of structural systems for lateral and gravity load resistance
   Course syllabus review & issuing of major Structural System Project

2. 8/29 A1. Lateral & torsional loads on buildings
   (esp. loads due to wind, earthquakes, retained earth & self-imposed by the structural system)
   A2. Intro to the 2d & 3d structural systems that are used to resist these loads
   (i.e., braced frames, shear walls, rigid frames, & various combinations of these)

3. 9/5 A3. Braced Frame Systems
   a. Basic form configurations & functioning of load-carrying mechanisms
   b. Range of example case studies

4. 9/12 A4. Shear Wall Systems
   a. Basic form configurations & functioning of load-carrying mechanisms
   b. Range of example case studies

5. 9/19 A5. Rigid Frame Systems
   a. Basic form configurations & functioning of load-carrying mechanisms
   b. Range of example case studies

6. 9/26 B1. Long-span systems – an overview
   B2. Tension-based Systems I: Stayed & Suspension Cable Systems
   a. Basic forms & functioning of load-carrying mechanisms
   b. Range of system configurations & example case studies

7. 10/3 B3. Tension-based Systems II: Cable Nets & Fabric Membranes
   a. Basic forms & functioning of load-carrying mechanisms
   b. Range of system configurations & example case studies

8. 10/10 No Class – Fall Break

9. 10/17 B4. Compression-based Systems I: Arches & Vaults
   a. Basic forms & functioning of load-carrying mechanisms
   b. Range of system configurations & example case studies

10. 10/24 B5. Compression-based Systems II: Domes & Cones
    a. Basic forms & functioning of load-carrying mechanisms
    b. Range of system configurations & example case studies

11. 10/31 B6. Compression-based Systems III: Shells & Folded Plate Systems
    a. Basic forms & functioning of load-carrying mechanisms
    b. Range of system configurations & example case studies

12. 11/7 B7. Bending-based Systems: Two-way Beam & Slab Systems, Trussed Systems & Frames, Space Frames, Vierendeel & Reciprocal Frame Systems
    a. Basic forms & functioning of load-carrying mechanisms
    b. Range of system configurations & example case studies

    11/12 (Sunday) *11:00am-12noon – project* submission deadline
    Model Projects and Illustrated Walk-through Projects submitted

13. 11/14 No Class – gallery exhibition

14. 11/21 No Class – gallery exhibition continued
    11/23 Thanksgiving Holiday

15. 11/26 12noon-4pm exhibition closes; post-exhibition model retrieval
    11/28 No Class

XII. Additional Resources and Readings

TBD

XIII. Co-meeting Courses

As indicated above in Sections III, V, VI, and XI, the main project requirement for the graduate level M.Arch students for this co-meeting course is different from that for B.Arch students. Specifically, whereas for B.Arch students the project requires the construction of a physical model of the structural system of a chosen recent building project developed and constructed by three students, for M.Arch students this requirement consists instead of having pairs of graduate students develop a strategic illustrated walk-through pathway for the structural system of a selected and approved building. [If certain graduate students wish to further develop and demonstrate their expertise with with a physical model project instead, this option is open upon request.]

XIV. Student work submission

- Students are required to format a comprehensive report of their work for the semester in an 11”x17” landscape format PDFs, as directed
- Physical models should be photographed and key creative walk-through digital files should be included and labelled into the final report
- Photos & digital files should be carefully & creatively formatted for submission and be labelled as follows: *Image title; Student last name, first name, and degree program (M.Arch/B.Arch)*
- A Cornell Box link will be provided for students to upload digital files directly

XV: NAAB

The department is required by the National Architectural Accrediting Board (NAAB), as part of the accreditation process, to collect specific course material for each course taught.

B. Student Criteria (SC): Student Learning Objectives and Outcomes

(*The 2020 NAAB Procedures, section 3.5.2, describes the types of evidence required for the assessment of SC.1 through SC.4. These criteria will be evaluated at the understanding level, while SC.5 through SC.6 will be evaluated at the ability level. Programs must provide evidence of the following criteria being addressed:*

SC.4 Technical Knowledge - How the course ensures that students understand the established and emerging systems, technologies, and assemblies of building construction, and the methods and criteria architects use to assess those technologies against the design, economics, and performance objectives of projects

SC.6 Building Integration - How the program ensures that students develop the ability to make design decisions within architectural projects while demonstrating integration of structural systems