Massachusetts Institute of Technology
4.411J/EC.713J/4.412
D-Lab Schools: Building Technology Laboratory

A Learning and Community Center in Masiaka, Sierra Leone

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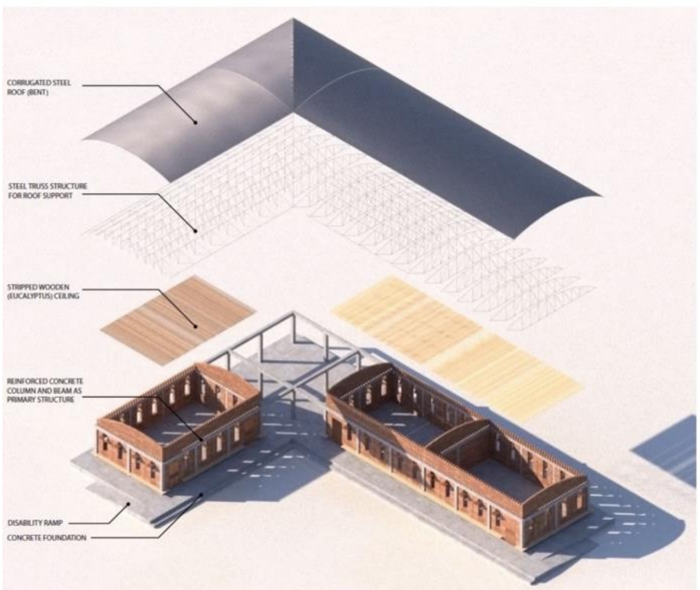

Units: 2-4-6 (Institute Lab)

Prerequisites: 8.01, 18.01

Schedule:	Lecture	Wednesday, 9:30-11:00 a.m., 1-132
	Lab	Monday 2:00-5:00 p.m., N51-350
	Office hours	to be announced and on request

Description

A year ago, students in 4.411J/EC.713J developed a design for the We Yone (Friendly Hands) Education Center (WYEC) now being constructed in Masiaka, Sierra Leone by long-term course partner, the US-Africa Children's Fellowship (USACF). This term, the course will focus on design improvements and performance assessment and technical analysis of the "Friendly Hands" Education Center to be constructed by USACF in Masiaka, Sierra Leone. The WYEC campus will include a library and literacy center, spaces for regional crafts and other economic activity, and a digital library and ITC center, with an external toilet block. Our goal is to work with USACF and the construction contractor, Surrah Sesay, to produce the best possible thermal comfort of the students, instructors and other community members in buildings that provide a safe working environment, are structurally sound, climate-appropriate, resource-respectful, and affordable. The focus on the physical environment for education builds on previous work within the Building Technology Program and the D-Lab Schools: Building Technology Lab course for schools in Cambodia, Haiti, Nepal, Pakistan, Sierra Leone, Singapore, and South Africa.

The of an education center in Sierra Leone springs from USACF's long engagement with children in Africa, the focus on D-Lab Schools on buildings in countries in Africa and Southeast Asia, and the past collaborations of MIT and USACF in schools and community centers in South Africa and Zimbabwe. Our investigation this term will include present and future climate analysis; building materials, structural design and construction methods that improve current local practice; daylighting; ventilation; indoor and outdoor thermal comfort; and building electrical systems, including photovoltaic panels. We will interrogate and, hopefully, improve the proposed design in realizable ways, both to boost performance of the new structure and to evolve the design for regions in Africa with different climates and local materials,

The course is set up as a series of short studies and lab-based projects, to be performed in teams formed to take best advantage of the skill sets of class participants. Planned experiments include fabrication and structural testing of low-cement blocks, daylighting measurements to establish reasonable threshold illuminance values for planned activities, and use of heat-stress meters to define acceptable and, perhaps, unacceptable environmental conditions. Necessary in-class instruction in simulation software will be supplemented by online tutorials. Results of these investigations will be compiled in a report, prepared in stages and submitted in final version at the end of the term.

Software we anticipate using includes Rhino and the associated Grasshopper visual scripting program, which will allow us to analyze climate, daylight, airflow, and thermal comfort within a design framework that easily obtains necessary geometrical information from a CAD model.

Course objectives:

- Develop an understanding of culture, education systems, climate and construction methods and materials in the country and local region of the school under consideration
- Develop an ability to analyze climate, its impact on the thermal comfort of school occupants and its influence on building design.
- Through experiments, application of engineering fundamentals and simulations, learn to quantify key aspects of building performance, including daylighting, moderation of indoor temperature, natural ventilation, and structural integrity and efficiency.
- Improve written and oral communication skills, including an ability to present design concepts and building performance to a non-technical audience.

Evaluation criteria:

The course grade will be based on participation in class and lab reports. Weekly assignments will require work that will be incorporated into the reports and may be presented orally in labs for discussion and feedback but will not be graded. Participation is crucial to the success of the course. Attendance in lab and lecture will be noted. Poor attendance, particularly in lab, will result in a reduced grade.

You will typically be encouraged to work in groups of 2-4, depending on the lab and available resources. Lab reports are prepared on a group basis: one report per group. Group composition may evolve during the term, as a function of the needs of students and the discretion of the instructor.

Course work will be weighted as follows:

Interim report #1	25%
Interim report #2	25%
Final report	20%
Final presentation	20%
Attendance and participation	10%

The course includes a final presentation that the MIT registrar will schedule during the final-exam period. There are no quizzes. Interim reports should be submitted on time; short extensions due to personal circumstances must be requested before the deadline. Interim lab reports received more than one week after the published deadline will be penalized 10% of full credit. The final report may be submitted as late as 5 p.m. on Tuesday, December 20, with no grading penalty; absent very short extensions for extraordinary circumstances, submittals after this date and time will receive no credit. The instructor and TA aim to return graded reports within one week of submittal. Schedule adjustments will be considered as necessary to accommodate major studio reviews, other significant deadlines, or the impact of local weather on experimental work.

An MIT 12-unit course, including this one, should require on average no more than 12 hours of work per week, in and out of class sessions. If your workload consistently exceeds this amount, please cut back and/or inform the instructor.

Personal and medical issues can make it hard to focus on academics. If you find that something is getting in the way of your ability to attend class, complete work, or take an exam, you should contact a dean in Student Support Services (S3). The deans will provide you with support and help you determine next steps. You can reach out to a dean you have worked with in the past, join their virtual help queue (https://sicp-s3.mit.edu/queue), or e-mail s3-support@mit.edu.

Provisional Schedule

Lecture	9/7	Course overview; intro to US-Africa Children's Fellowship; review of building technology studies of schools in developing (and recently developed) countries; thermal comfort and climate fundamentals
Lab	9/12	Climate investigation with Climate Studio or alternatives; morphed weather files to estimate climate change; thermal comfort metrics and measurements
Lecture	9/14	Outdoor and indoor thermal comfort metrics; prediction of satisfactory classroom conditions
Lab	9/19	USACF visit (in-person or virtual; date TBD): Mark Grashow and Abdulai Bah; thermal comfort measurements with Kestrel heat-stress trackers
Lecture	9/21	Lighting fundamentals; daylight measurements to establish/confirm illuminance target
Lab	9/26	Sharing thermal comfort and daylight data and analysis. Daylight and glare simulations and physical models to assess window area and location
Lecture	9/28	Solar radiation for electric power: relating PV panels and battery storage to power demands
Lab	10/3	PV calculations
Lecture	10/5	Thermal fundamentals: steady-state heat transfer, properties of wall and roof materials and windows
	10/7	**Add Date**
	10/10	**Indigenous Peoples Day holiday** – no class
Lecture	10/12	guidelines for interim report #1
Lab	10/17	Fundamentals of natural ventilation: hydrostatic equation, ideal gas law, Bernoulli's equation, orifice equation
Lecture	10/19	Buoyancy- and wind-driven airflows; airflow mass and energy balances **interim report #1 due**
Lab	10/24	materials, construction, and structures with John Ochsendorf; fabrication of low-cement blocks
Lecture	10/26	Roof and wall design: materials and structure
Lab	10/31	Testing to failure of low-cement blocks
Lecture	11/2	Whole-building structural systems; embodied energy and carbon

Lab	11/7	Natural ventilation and control of window openings with GSD PhD student Sunghwan Lim (TBD); Indoor and outdoor airflow simulations using computational fluid dynamics and airflow-energy balances; Off-ramp for design-builders (as distinct from simulators): window shutters/shades, furniture prototypes, latrines, other Off-ramp for design simulators inspired by Francis Kéré, with an interest in estimated performance
Lecture	11/9	Airflow in the wind shadow of other buildings; Thermal comfort enhancement: local and room-level increases in airflow; Indoor air quality, including particulates and CO_2guidelines for interim report #2
Lab	11/14	whole-building energy balances using Rhino and ClimateStudio or Honeybee to estimate indoor thermal comfort, identify overheating periods and calculate electricity consumption for lights and fans
Lecture	11/16	Rooftop energy systems, including photovoltaic electricity, solar-thermal systems, and radiative cooling **interim report #2 due**
Lab	11/21	Assessment of comfort deficit: over-coming excessive heat and humidity
Lecture	11/23	Design charrette preview: interrogating or improving the "MIT design"
	11/23	**Drop Date**
	11/25-26	**Thanksgiving and Institute holidays**
Lab	11/28	Design charrette: improving the MIT design
Lecture	11/30	Design of PV power and energy storage systems
	TDB	**D-Lab Fall Showcase, 7-9 pm (placeholder for our contribution)**
Lab	12/12	Assessment of simulations for final report and presentation
Lecture	12/14	**Final report due**
	12/14	**Last day of classes**
	12/16-22	MIT final exam period; the MIT registrar will schedule a slot for our final presentations; **Final presentation due**

References (no required textbooks)

Murdoch, Joseph B. *Illumination Engineering From Edison's Lamp to the Laser Second Edition* 2003, Vision Communications ISBN 1-885750-05-6

Reinhart, Christoph F. *Daylighting Handbook I: Fundamentals, Designing with the Sun* 2014 ISBN 9780692203637

Reinhart, Christoph F. *Daylighting Handbook II: Daylight Simulations | Dynamic Facades* 2018 ISBN 9780578407098

Canvas

This course has a Canvas site, where homework assignments and instructions will be posted and where lab reports can be submitted electronically.

Academic integrity + honesty

Academic integrity is a serious issue. Data sources must include attribution. Lab reports must reflect the thoughts and efforts of team members, unless noted. Please familiarize yourself with MIT's Academic Integrity expectations at http://web.mit.edu/academicintegrity/.

Software

At appropriate times in the course, you will be asked to install most or all of the following software, for which (near) current download links are provided.

Rhino 6.0 or 7.0 - https://www.rhino3d.com/download - Grasshopper is included with the download. We have used the Windows version in the past. Ladybug Tools are now available for Windows and Mac OS but those who use Climate Studio will need the Windows version. Proceed with caution. There is a free 90-day evaluation version; longer-term usage requires a $195 educational license or access through the Department of Architecture's IT group, https://stoa.mit.edu/.

Ladybug and Honeybee (and other insects!) – https://www.ladybug.tools/index.html – the insects provide grasshopper plug-ins for analysis and visualization of climate, thermal comfort, building energy use and airflow

CC WorldWeatherGen (http://www.energy.soton.ac.uk/ccworldweathergen/) morphs weather files to account for projected regional climate change.

CoolVent - http://coolvent.mit.edu/download/ - a good way to assess the impact of wind-driven or buoyancy-driven airflows on building temperatures. Windows only.

ClimateStudio – https://www.solemma.com/climatestudio version 1.8 is the latest. https://www.climatestudiodocs.com/Installers/download.php?software=cs&version=networked -- includes daylighting and building energy analysis and visualization; we will use it for daylighting analysis. The MIT license code will be provided separately. Windows only.

Ladybug Tools' **Dragonfly** or **ANSYS Fluent** computational fluid dynamics (CFD) programs. Download and installation instructions will be provided at the appropriate time.

CBE Thermal Comfort Tool - http://comfort.cbe.berkeley.edu is an online program developed by the Center for the Built Environment at UC Berkeley that locates specified environmental and occupant conditions within a region of acceptable thermal parameters.

CBE Clima Tool - https://clima.cbe.berkeley.edu is an online program that displays climate data extracted from EnergyPlus weather (epw) files.

Climate Consultant (http://www.energy-design-tools.aud.ucla.edu) is a freely downloadable tool that runs under Windows or Mac OS and provides a relatively comprehensive set of non-customizable graphical presentations of data from standard weather files. We prefer Ladybug and the CBE thermal comfort and climate tools but acknowledge that Climate Consultant is easy to use for standard climate information.

Eddy3D (https://www.eddy3d.com) is a freely downloadable tool that runs in Grasshopper (Windows only) to assess airflow around buildings and wind pressures on building surfaces.