CAE 463/524: Building Enclosure Design

Fall 2012

Illinois Institute of Technology
Department of Civil, Architectural and Environmental Engineering

3 credit hours

Course Unique Number(s)
CAE 463 Section 1: 10411 (undergraduate)
CAE 463 Section 2: 13228 (undergraduate online)
CAE 524 Section 1: 10421 (graduate)
CAE 524 Section 2: 13229 (graduate online)

Classroom and Meeting Time
Stuart Building, Room 204
Mondays
6:25 PM – 9:05 PM

Course Website
http://built-envi.com/courses/cae-463-bed-f12/

Prerequisites
CAE 331 Building Science

Instructor
Brent Stephens, Ph.D., Assistant Professor
Office: Alumni Memorial Hall Room 212
Phone: (312) 567-3356
Email: brent@iit.edu
Website: www.built-envi.com

Office Hours
By appointment.
I am generally around my office, Alumni Hall #212, most of the day Monday through Friday, and you can always stop by. To ensure that I will be there, please email me to schedule an appointment.

Course Catalog Description
Design of building exteriors, including the control of heat flow, air and moisture penetration, building movements, and deterioration. Study of the principle of rain screen walls and of energy conserving designs. Analytical techniques and building codes are discussed through case studies and design projects.

Course Objectives
To introduce students to the design of building enclosures, elements of which include walls, floors, roofs, and intentional openings. By taking this course students will be able to:

1. Design and assess building enclosure elements for heat transfer, airflow, and moisture control.
2. Be proficient in current building codes as they pertain to building enclosure design.
3. Critically analyze designs for advanced building enclosures for their impacts on energy use, airflow, and potential moisture issues.

Textbook (highly recommended)
Straube, J. and Bernett, E. 2005. *Building Science for Building Enclosures*. Building Science Press. Westford, MA. ISBN: 0-9755127-4-9.

References (optional; will be given handouts when necessary)

ASHRAE 2009. *Handbook of Fundamentals.* American Society of Heating, Refrigerating, and Air-Conditioning Engineers, Atlanta, GA.
ASHRAE 90.1-2010. *Energy Standard for Buildings Except Low-Rise Residential Buildings.*
Moss, K.J. 2007. *Heat and Mass Transfer in Buildings* (Second Edition). Taylor & Francis, New York, NY. ISBN: 978-0-415-40908-7.
Kuehn, T.H., Ramsey, J.W., and Threlkeld, J.L. *Thermal Environmental Engineering*. Prentice Hall, Saddle River, NJ. ISBN: 0-13-917220-3.
Kreider, J.F., Curtiss, P.S., and Rabl, A. *Heating and Cooling of Buildings: Design for Efficiency* (Second Edition), CRC Press, Taylor & Francis Group, Boca Raton, FL. ISBN: 978-1-4398-1151-1.

Course Topics and Schedule

(See last two pages of syllabus)

Homework Assignments

There will be several homework assignments during the course that will involve hand calculations, development of spreadsheets, and learning the basics of some software packages typically used in industry. Some general rules for homework assignments are as follows:

- Homework (HW) assignments will be posted on blackboard and emailed to students.
- HW assignments will typically be due one week after they are assigned.
- Students handing in HW assignments should submit neatly printed HW.
- Multipage submissions must have all pages stapled together.
- Students enrolled in the online course will submit HW via the Blackboard digital drop box. Handwritten HW must be scanned and converted to PDF by online students. Multiple pages must be converted to a single PDF for submission.
- Graduate students will be expected to perform more advanced analyses in their HW.

Exams

One take-home exam will be given with a tentative date of October 22, 2012. Students will have 48 hours to complete the exam and return to Dr. Stephens. A final exam is not currently scheduled for this course. A final report and presentation is currently scheduled to take place the last week of classes; I will also maintain the scheduled exam period (December 3, 2012) as a backup for our presentation time.

Projects

There will be two projects in this course. The first is an assessment and design project where class members will work to critically assess the building enclosure of a building on IIT's main campus and to suggest improvements for increased energy and moisture performance without changing the aesthetics of the building. I have ordered an infrared camera so we can take thermal images of the buildings and investigate for thermal bridges and other issues.

The second and final project is a research project where groups of 2-3 students research high performance building enclosure constructions, develop a technical report describing examples in practice and quantifying heat, air, and moisture transport within a typical design, and give their summaries in a classroom presentation. Graduate students are expected to perform a more detailed analysis and format their report as a more formal research article/conference paper.

Grading

Course grading will be done primarily through homework assignments, one exam, and two projects. This is a mixed undergraduate and graduate course; higher expectations will be placed upon deliverables from graduate students.

Grades will be determined by the total number of points accumulated through homework assignments, projects, and exams, with a small amount of potential credit for class participation. The total number of points available in each category is listed in the table below. The number of required points for various grades is also given below.

Grading Table

Category	Available Points
Homework	200 (20%)
Project 1	150 (15%)
Final project	350 (35%)
Exam	300 (30%)
Total	1000 (100%)

Grade	Required Points
A	≥ 900 (90%)
B	800-899 (80-89.9%)
C	700-799 (70-79.9%)
D	600-699 (60-69.9%)
F	< 600 (60%)

Contribution to Meeting Curriculum Areas

Curriculum Area	Percentage
Basic Science & Math	
Humanities/Social Sciences	
Basic Engineering	
Introductory Architectural Engineering	20%
Professional Level Architectural Engineering	80%

Learning Outcomes and Expected Knowledge Gain

Upon completion of this course students will have proficiencies in building design as it pertains to enclosures such as walls, roof and openings. Furthermore, students will know the enclosure design requirements including those related to the heat and air flow, serviceability issues (such as building vibration and deterioration) and relevant code issues.

Performance Indicators

Performance indicators used in student learning outcomes are marked with 'X' in the following table.

Performance Indicator	Description	
I	Presentation by students (oral, poster, PowerPoint, etc.)	X
II	Term papers	X
III	Group projects (periodic progress reports project final report are required)	X
IV	Presentation by outside speakers on contemporary topics	X
V	Ethics, presentation and case study discussions	
VI	Reports (lab report, summary report on design of experiment, data analysis, research findings, etc.)	X
VII	Group discussions on understanding of profession, liabilities, professional development, etc.	
VIII	Evaluation of students' work through interviews, one-to-one meetings with students, and class discussions	X
IX	Review of learning outcomes with students and quiz on specific program learning outcomes	X
X	Overall performance in exams, homework, projects, attendance, etc.	X

Personal Problems
If you have illness or personal problems that will affect your performance during the course of the semester, please let me know as soon as possible. "After the fact" provides little protection unless there are extreme circumstances. Contact me by phone or e-mail at any time.

Students with Disabilities
Reasonable accommodations will be made for students with documented disabilities. In order to receive accommodations, students must obtain a letter of accommodation from the Center for Disability Resources. The Center for Disability Resources (CDR) is located in Life Sciences Room 218, telephone (312) 567-5744 or email: disabilities@iit.edu.

Relationship of Course to ABET Outcomes

Outcome	Description	Extent of Coverage
a	Apply knowledge of math, engineering, science	3
b1	Design and conduct experiments	
b2	Analyze and interpret data	2
c	An ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability	5
d	An ability to function on multi-disciplinary teams	1
e	An ability to identify, formulate, and solve engineering problems	4
f	A respect for, and understanding, the professional and ethical responsibility	3
g	An ability to communicate effectively	2
h	The broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context	2
i	A recognition of the need for, and an ability to engage in life-long and continuing education	1
j	A knowledge of contemporary issues within civil engineering	3
k	An ability to use techniques, skills, and tools in engineering practice	4
l	Ability to use knowledge gained in courses in a major capstone design project	4

1 = minimum coverage in the course; 5 = major coverage in the course

Academic Honesty
It is your responsibility to be familiar with IIT's Code of Academic Honesty. The Code of Academic Honesty can be found on page 243 of the Undergraduate Bulletin: http://retention.iit.edu/resources/bulletin_2008_2010.pdf.

You must submit your own work for homework. You are encouraged to discuss and even work with other students on homework (unless explicitly told otherwise), but material that is submitted must be your own work. For group project assignments, each group is to submit their own work. For a first violation of the IIT Code of Academic Honesty for a homework or project, the homework will receive a grade of zero for all involved students and the students will be reported to the Designated Dean for Academic Discipline (DDAD). For a first violation of the Code of Academic Honesty for a major project or an examination, the student will receive a failing grade for the course and the student will be reported to the DDAD. For a second violation, the student will receive also failing grade for the course and be reported to the DDAD.

Course Topics

1. Introduction: Purpose and importance of building enclosure design • Review of environmental conditions • Review of heat, air, and moisture fundamentals • Typical building enclosure components and materials	1 week
2. Heat transfer in building enclosures • Solar orientation • Review of radiation, conduction, and convection • Calculating rates of heat transfer • Calculating heat resistance of enclosures	2 weeks
3. Airflow in building enclosures • Enclosure airflow fundamentals • Design requirements for air barriers • Estimating and measuring air infiltration • Designing for natural ventilation	0.5 weeks
4. Moisture flows in building enclosures • Water vapor transport fundamentals • Calculating moisture transfer rates • Moisture storage in porous materials • Water vapor diffusion	1 week
5. Moisture problems and prevention • Mold growth, corrosion, material decay, freeze-thaw • Designing for moisture control • Controlling condensation • Controlling rainwater	1 week
6. Dynamic heat, airflow, and moisture • Impacts on heating and cooling loads and energy use	0.5 weeks
7. Analytical and software techniques in building enclosure design • THERM, WUFI, ComCheck	1 week
8. Applications: Exterior walls and windows • Physics and basic design requirements • Design requirements for energy efficiency • Design for multiple climates	2 weeks
9. Applications: Roofs and floors • Physics and basic design requirements • Design requirements for energy efficiency	1 week
10. Advanced/high performance building enclosure designs • Green roofs, double-skin façades, alternative insulation materials, PV integration, phase change materials, advanced windows, etc.	1 week
11. Impacts of building enclosures on indoor air quality	1 week
12. Final project presentations	1 week
Total	13 weeks

Tentative Course Schedule

Date	Topic	Suggested reading for this date:	Due date for:
08/20/12	Purpose and importance of building enclosure design	Straube Ch. 2-3; Lstiburek 2004	
08/27/12	Heat transfer in building enclosures	Straube Ch. 4-5	HW 1
09/03/12	Labor Day – No class		
09/10/12	Heat transfer in building enclosures (continued)		
09/17/12	Heat transfer in building enclosures (finish)	Lstiburek 2012	Finalize first project team & campus building
09/24/12	Moisture flows in building enclosures	Straube Ch. 6; Kazmierczak 2010; Karagiozis et al. 2010	HW 2
10/01/12	Moisture problems and prevention	Straube Ch. 9-10; OAA, *The Rain Screen Wall System*	HW 3
10/08/12	Fall Break Day – No class		Final project topic justification due
10/15/12	Air infiltration	Straube Ch. 7; Younes et al. 2012	HW 4 + Final project group consultation
10/22/12	Glazing and heat transfer through windows • Exam review	Selkowitz 2011; Straube 2008	Take-home exam (released 10/23)
10/29/12	Applications: Daylighting (*Guest lecture from Ray Clark, former partner, SOM*)		Take-home exam due
11/05/12	Heat transfer: Floors, roofs, and thermal mass • Exam solutions	Asadi et al., 2012; Asan 2006; Medina 2000; TenWolde 1997	
11/12/12	Energy use and the enclosure		IIT campus building project
11/19/12	Applications in building enclosures • Campus project overview		
11/26/12	Impacts of building enclosures on indoor air quality • Final project presentations	Liu and Nazaroff 2001; Stephens and Siegel 2012	~Half of project presentations
12/3/12	Final project presentations • Final exam period (7:30 to 9:30 PM)		Other ~half of final project presentations Final project report due

*Note that two class periods will be interrupted by IIT's official academic calendar: Labor Day (September 3, 2012) and Fall Break Day (October 8, 2012)

Suggested Readings

Asadi, S., Hassan, M., and Beheshti, A. Performance evaluation of an attic radiant barrier system using three-dimensional transient finite element method. *Journal of Building Physics*.

Asan, H. 2006. Numerical computation of time lags and decrement factors for different building materials. *Building and Environment* 41:615-620.

Karagiozis, A., Desjarlais, A., Kuenzel, H., and Holm, A. The Evolution of Hygrothermal Design: WUFI to WUFI-Plus. *Journal of Building Enclosure Design*, Summer 2010.

Kazmierczak, K. Using 3D thermal modeling to improve performance requirements. *Journal of Building Enclosure Design*, Summer 2010.

Liu, D-L. and Nazaroff, W.W. 2001. Modeling pollutant penetration across building envelopes. *Atmospheric Environment* 35:4451-4462.

Lstiburek, J. Built Wrong from the Start. *Fine Homebuilding* April/May 2004, pg. 52-57.

Lstiburek, J. Thermal Bridge Redux. *ASHRAE Journal*, July 2012.

Medina, M. 2000. On the performance of radiant barriers in combination with different attic insulation levels. *Energy and Buildings* 33:31-40.

Ontario Associations of Architects. *The Rain Screen Wall System*.

Selkowitz, S. High-Performance Building Enclosures: Combining View with Energy Efficiency. *Journal of Building Enclosure Design*, Summer 2011.

Stephens, B. and Siegel, J.A. 2012. Penetration of ambient submicron particles into single-family residences and associations with building characteristics. Indoor Air, doi: 10.1111/j.1600-0668.2012.00779.x.

Straube, J. and Burnett, E. 2005. *Building Science for Building Enclosures*. Building Science Press. Westford, MA. ISBN: 0-9755127-4-9.

Straube, J. 2008. Building Science Insight: Can highly glazed facades be green?

TenWolde, Anton. 1997. FPL roof temperature and moisture model: Description and verification. Res. Pap. FPL–RP–561. Madison, WI: U.S. Department of Agriculture, Forest Service, Forest Products Laboratory. 48 p.

Younes, C., Shdid, C.A., and Bitsuamlak, G. 2012. Air infiltration through building envelopes: A review. *Journal of Building Physics* 35(3):267-302.