Graduate Program in Historic Preservation
Stuart Weitzman School of Design, University of Pennsylvania

HSPV 5510 ***Building Pathology***
Michael C. Henry, PE, RA **Adjunct Professor of Architecture**

Course Syllabus

Class Meetings
The class will meet on Fridays, from 1:45 PM to 4:45 PM (EST/EDT) in-person in Meyerson Hall, Room B7.
If in-person classes are not possible/advisable due to weather and/or health risk factors, class meetings will be held on-line via *Zoom*.

Teaching and Learning Platforms
Canvas will be used to access course materials, lecture slides, readings, quizzes, and tests.
Class meetings will not be recorded unless a student cannot attend due to exceptional circumstances, such as a health quarantine.

Communications
Each student is expected to meet with me at least twice during the semester.
Office hours: By appointment, *via Zoom*, 8:30 AM to 12:00 AM (EDT/EST), Thursdays
E-mail: henrmic@design.upenn.edu
Include "HSPV 5510" in the subject heading of your email to me.
Please add mhenry@watsonhenry.com to your "Safe Senders" list.

Teaching Assistant: Veilleux, Anna Marie, veilleux@design.upenn.edu
Please contact the Teaching Assistant regarding scheduling meetings with me, course materials in Canvas, or if you wish for me to review/repeat/explain course content in class.

Teaching and Learning
Class meeting time will be structured to maximize active learning and interaction among participants.
Your participation in discussions of lecture content and in engagement in exercises is expected.
Your thorough preparation before class, including the readings and lecture slides is required.

The final assignment consists of a professional consultation which will be submitted incrementally over the semester, so that feedback can be provided to you in time for you to conduct more research and refinement of you final work product.

Feedback on the effectiveness of the methods used in this course will be welcome, so that we can incorporate mutually agreeable adjustments and introduce improvements as the course proceeds through the semester. Your candid feedback on course content, readings, class exercises and teaching methods is encouraged so that the course may be continuously developed and improved. You may deliver your course feedback directly to me, or through the Teaching Assistant. Real time feedback, rather than feedback at the end of the course, is preferred.

Use of Artificial Intelligence (AI) is Prohibited
You are not allowed to use generative AI (such as tools like Chat-GPT) for your work in this class. Using such tools will be considered a violation of Penn's Code of Academic Integrity and suspected use will be reported to the Center for Community Standards and Accountability. Please contact me if you have questions about this policy.

Course Description
Buildings, their sites, systems and supporting infrastructure embody substantial investments in capital, labor, and energy. Historic buildings embody the added value of their architectural, cultural, or historic significance.

The post-construction performance and function of buildings will inevitably decline due to various pathologies. These pathologies are enabled by factors in the environment including climate change, by past use and occupancy of the building and by time. Eventually, the aggregate effect of these pathologies necessitates appropriate interventions to slow the loss of, or reinstate, a building's utility, functional performance and appearance. Appropriate interventions address the causal factors of the pathologies, slowing deterioration/damage with minimal loss of architectural, cultural, or historic significance.

Building Pathology is the study of deterioration processes that can ultimately determine a building's survival or loss. The course presents building pathologies as dynamic systems with causal factors such as energy and moisture acting over time, thus informing prevention as well as remediation. The course prepares the historic preservation professional to consider existing conditions and identify the underlying enabling factors and causal mechanisms of deterioration and loss. The course also prepares the architect to identify potential building longevity problems when designing new buildings.

Building Pathology will address:
- A *systemic approach* to understanding building deterioration, considering the building, its physical, economic, and climatic contexts, its occupancy and use, and the implications of changes in these with time.
- How systems thinking, visualization of information, and creative problem solving are essential tools in understanding complex building pathologies.
- How bias, critical thinking, active listening, and visual awareness affect the quality of our building observation and assessments.
- The properties of building materials, their comparative values as performance assets and as potential vulnerabilities to deterioration.
- The mechanisms of building deterioration - mechanical, hygrothermal, biological and electrochemical - as dynamic systems acting over time. The causal factors necessary for the deterioration mechanisms to occur and the contextual sources for these factors. How these mechanisms occur singly or synergistically in a building's structure, enclosure, or systems.
- The investment of capital, labor and energy needed to maintain historically significant buildings in good condition.
- The implications of preventive conservation, sustainability, and adaptability for building survival.
- How to set objectives for remedy, mitigation, and prevention of deteriorative mechanisms once the causal mechanisms are known and how to Identify and evaluate intervention strategies for achieving the objectives.

Learning Objectives
For successful completion of the course, you should be able to:
- Think of buildings systemically in spatial and temporal dimensions.
- Understand building deterioration as a dynamic system, rather than symptomatic results.
- Visualize data and evidence concerning deterioration so that causal factors may be correctly identified.
- Recognize how diagnostic bias leads to misidentification of causal factors of deterioration.
- Recognize building materials for their vulnerabilities to deterioration as well as their durability.
- Know the primary mechanisms of deterioration in buildings, the necessary and sufficient causal factors for each mechanism, and the potential for synergistic interaction between different mechanisms.
- Express building pathology issues in quantitative and qualitative terms, using professional terminology.
- Research technical information on building pathologies and building materials in professional journals.
- Set the objectives to mitigate, remedy or prevent deterioration and identify potential strategies.
- Recognize the importance of utility and function for the survival of buildings.
- Prepare professional-quality technical reports that demonstrate application of the above.

Learning - Your Responsibilities as a Student

- **Attendance**

You are expected to attend all classes. Notify me and the TA by email before class if you must be absent.

- **Conduct in Live and On-line Class Meetings**

You should treat class meetings as if you are in a business meeting with other professionals. Eliminate distractions. Turn off phones, email, and texting apps during class. Do not consume food during class.

Required Readings for the Course

Required readings - either in the form of selected portions of books or as published articles - are listed for each class meeting in this syllabus.

Articles required for each class meeting can be accessed through Canvas under the tab "Modules" Tab.

The complete books from which selected readings are listed can be accessed through Canvas under the tab "Course Materials @ Penn Libraries":

Blockley, David. *Structural Engineering – A Very Short Introduction.* Oxford: Oxford University Press, 2014.

Brand, Stewart. *How Buildings Learn – What Happens after They're Built*. New York, NY: Viking, Penguin Books, USA, 1994.

Ching, Francis D. K. *Building Construction Illustrated*, 6th Edition or later. New York, NY: Wiley, 2014 or later.

Harris, Samuel Y. *Building Pathology – Deterioration, Diagnostics and Intervention*. New York, NY: John Wiley & Sons, Inc, USA, 2001.

Meadows, Donella H. *Thinking in Systems, a primer.* White River Junction, VT: Chelsea Green Publishing, 2008.

Taylor, J., Henry, M. C., et al., *Managing Collection Environments: Technical Notes and Guidance*. Los Angeles: Getty Conservation Institute, 2023. (also at https://hdl.handle.net/10020/gci_pubs_mce_technical_notes)

Tufte, Edward R. *Beautiful Evidence*. Cheshire, CT: Graphics Press, LLC, 2006.

Watt, David S. *Building Pathology – Principles and Practice.* London: Wiley-Blackwell, 2008.

- **Reflections on the Previous Class**

Prior to the second class meeting, and before each subsequent class meeting, you must post your reflections on content from the previous class and readings on *Canvas*.

- **Class Exercises**

Class exercises will apply information or methods addressed by the readings and lectures and are an important part of the learning process. Class exercises require reasoning, analysis, basic mathematical calculations, and sketching. Some exercises will be done individually; other exercises will be collaborative.

You will typically need your tablet or computer, graph paper and writing instruments to complete the class exercises.

- **Test of Knowledge**

The "closed book" test of knowledge is your opportunity to demonstrate that your command of essential information and problem-solving skills covered by the readings and lectures. You will need a computer, graph paper and writing instruments to complete the test.

- **Final Assignment Deadline**

The deadline for the final assignment is firm and there will be ample time for you to plan and execute the assignment. One letter grade will be deducted for late submission of the assignment.

- **Academic Integrity**

Honesty is fundamental to your future practice as a professional and academic honesty is fundamental to our community at the University of Pennsylvania. Honesty includes attributing and citing the sources used in your assignments.

The UPenn Code of Academic Integrity can be found at https://catalog.upenn.edu/pennbook/code-of-academic-integrity/ *A confirmed violation of that Code in this course will result in failure for the course.*

Metrics for Student Performance

Letter grades and their numerical equivalents will be based awarded upon successful completion of the course. The final grade will be based on the following allocation:

- Participation in class 30 %
- Test of Knowledge 30 %
- Assignment 40 %
- Total (maximum) 100 %

The calculated grade will be adjusted to reflect unexcused absences and late assignments.

Participation in class will be based on your individual:

- Preparation, including demonstration of retention and comprehension of the readings;
- Exercises - participation and outcomes;
- Engagement in discussions;
- Reflections on class content in *Canvas*.

The *Test of Knowledge* will be scored based on based on points earned with correct answers. Letter grades will be assigned based on distribution of the numeric scores of the class.

The Assignment will be graded on:

- Focused, substantive and concise content, founded on clear and logical analysis, substantiated by facts, research beyond the course materials and citations, including professional citations from outside the course readings;
- Clear and logical narrative exposition of the information, substantially free of grammatical, punctuation and spelling errors;
- Graphical presentation of key concepts illustrating the important or complex points of the narrative;
- Conformance with format requirements.

The grading rubric for the Assignment will be:

- A Exceptional work, equivalent to professional quality, thorough grasp and synthesis of all course content.
  Thorough preparation for class, demonstrated by engagement and participation.
  Writing: Logically organized, clear and concise with correct use of technical terminology.
  Research: citations from professional journals and publications other than class readings.
  Graphics: multi-variant, demonstrating causality & connections, clear and compelling.
- B Very good work, near-professional quality, thorough grasp and synthesis of nearly all course content.
  Rare lapses in preparation for class, occasional lack of engagement and participation in class.
  Writing: rare lapses in clarity or application of technical terminology.
  Research: citations from class texts and readings.
  Graphics: dual variant, showing causality or correlation, clear and convincing.
- C Average work, sub-professional quality, understanding of basic information.
  Marginal class preparation, moderately engaged, occasional participation.
  Writing: Weak organization or structure, poor application of technical terminology.
  Research: citations on technical matters from popular web sources, such as Wikipedia.
  Graphics: single variant, clear.
- F Unacceptable work.

The Final Assignment - *Building Pathology Consultation*: Overview, Format Submission & Disposition
In partial fulfillment of the course, you will work in teams of two, and each team will submit two to three *Building Pathology Consultations*. Each consultation consists of a professional-level letter addressing a specific building pathology problem. The letter (up to 10 pages of text) will be supplemented by appendices and graphics.

In preparing the *Building Pathology Consultations*, you will apply and extend critical concepts, fundamental principles, methods and information from the lectures and readings, supplemented by your own research in professional and technical publications. This effort will provide active, student-centered learning in the context of authentic, real-world building problems.

Your Consultation must be a clear and logical exposition of the facts,[1] substantially free of grammatical and spelling errors. Your graphics should clearly illustrate the important or complex points of the narrative.[2] Your conclusions and recommendations must be substantiated by facts and reflect a rational thought process.

The *Building Pathology Consultation* is a digital document file (pdf) using:
- 8.5 by 11.0-inch paper in portrait orientation for text and small graphics;
- 11.0 by 17.0-inch paper in landscape orientation for large graphics
- Calibri font, 11-point, black print, single spaced lines for all text
- Margins set at 1.25 inches (binding edge), 1.00 inches (other edges)
- Single-line footer with Consultation Number (left) and page number (right)
- Pages numbered sequentially: 1, 2, …for report body; A1, A2, … for appendix A, similar for B, et cetera.
- Endnotes
- Photographs, images, and charts/graphics:
  Landscape format (top edge to binding edge) or portrait format.
  Colors in charts and graphs must be accessible to readers with color-blindness.
  Image size and resolution must be sufficiently legible when printed.
  Captioned with self-evident descriptive text, source name and date.
- Cover (Title) page with:
  Course number, title and program and date of report.
  Each student's printed name and signature with statement "I have contributed equally with my team partner(s) in this assignment."

Submission of Final Assignment:
- Prepare a **digital copy** of the entire assignment as a single.pdf file and title the file: "2025 HSPV5510 Final Assignment xxxxx and xxxxx" where xxxxx are the names of the student team members.
- **Self-Evaluation:** Each team member must complete a self-evaluation of the final assignment using the grading rubric and submit the self-evaluation as an attachment to the assignment.
- Upload the digital copy of the *Building Pathology Consultation* and the self-evaluations **before the time and date** specified in the Class Schedule portion of this syllabus.

[1] *Elements of Style Illustrated* by William Strunk, Jr. and E. B. White is a classic guide to writing. The current edition is delightfully illustrated by Maira Kalman.

[2] *The Visual Display of Quantitative Information, Second Edition* by Edward R. Tufte provides an excellent review of graphical presentation of information.

Other Useful Resources

The following resources references will be useful in the course and in the final assignment:

American Concrete Institute. Home page. https://www.concrete.org/

American Society of Civil Engineers.
ASCE 11-99 Guideline for Structural Condition Assessment of Existing Buildings. New York, NY, USA: ASCE, 1999. https://ascelibrary.org/doi/book/10.1061/9780784404324
ASCE 30-14 Guideline for Condition Assessment of the Building Envelope. New York, NY, USA: ASCE, 2014. https://ascelibrary.org/doi/book/10.1061/9780784413258#

American Society for Testing and Materials. Home page. https://www.astm.org/

Architectural Engineering and Design Management. This publication analyses and discusses the integration of the main stages within the process of design and construction and multidisciplinary collaborative working between the different professionals involved. Taylor & Francis. http://www.tandfonline.com/action/journalInformation?journalCode=taem20#.Vpv4JfkrIfI

Architectural Science Review. This publication presents papers on environmental issues, covering topics such as thermal comfort, lighting, and sustainable architecture. Taylor & Francis. http://www.tandfonline.com/action/journalInformation?journalCode=tasr20

Association for Preservation Technology. Home page. http://www.apti.org/

Brick Industry Association. *Technical Notes*. http://www.gobrick.com/TechnicalNotes/tabid/7658/Default.aspx

Building and Environment. The International Journal of Building Science and its Applications. Elsevier. http://www.journals.elsevier.com/building-and-environment/

Building Research and Information. This publication focuses on buildings, building stocks and their supporting systems, reflecting the complexity and linkages between culture, environment, economy, society, organizations, quality of life, health, well-being, design, and engineering of the built environment. Taylor & Francis. http://www.tandfonline.com/action/journalInformation?show=aimsScope&journalCode=rbri20#.Vpv5xPkrIfI

Building Science Corporation. *Building Science Digests* and *Building Science Insights* series. http://www.buildingscience.com/index_html

Canadian Architect. Architectural Science Forum series. Ted Kesik. https://www.canadianarchitect.com/?s=Architectural+Science+Forum

Construction and Building Materials: An international journal dedicated to the investigation and innovative use of materials in construction and repair. Elsevier. http://www.journals.elsevier.com/construction-and-building-materials/

Energy and Buildings. An international journal devoted to investigations of energy use and efficiency in buildings. Elsevier. *http://www.journals.elsevier.com/energy-and-buildings*

Engineering Weather Data: a compilation of National Climate Data Center Charts and Tables for worldwide locations as used in the course. Can be accessed for free at University of Indiana University, Bloomington website. https://webapp1.dlib.indiana.edu/virtual_disk_library/index.cgi/4910250/FID2605/engwx/EngineeringWeather.html at bottom of page select either "Download" for the entire file or "Browse" then open "EngineeringWeather.html" to find a location.

Forest Products Laboratory. Home page. http://www.fpl.fs.fed.us/

International Journal of Architectural Heritage. This publication provides a multidisciplinary scientific overview of existing resources and modern technologies useful for the study and repair of historical buildings and other structures, including information on history, methodology, materials, survey, inspection, non-destructive testing, analysis, diagnosis, remedial measures, and strengthening techniques. Taylor & Francis. http://www.tandfonline.com/action/journalInformation?show=aimsScope&journalCode=uarc20#.Vpv61PkrIfI

Journal of Building Engineering. An interdisciplinary journal that covers all aspects of science and technology concerned with the whole life cycle of the built environment, from the design phase through to construction, operation, performance, maintenance, and its deterioration. Elsevier. http://www.journals.elsevier.com/journal-of-building-engineering

Journal of Building Physics. Covers on-structural performance of a building and particularly in heat, air, moisture transfer and includes: insulation and building envelope materials and systems including polymeric, mineral, cellulose-based, and composites, building interactions with the environment, occupants, and allied building materials, components, and sub-systems, green roofing, double skinned envelopes and interaction of building enclosure with mechanical systems. Sage. http://intl-jen.sagepub.com/

Journal of Cultural Heritage. A multidisciplinary journal of science and technology for conservation and awareness; presents innovative methods concerning all aspects of science and technology of cultural heritage as well as interpretation and theoretical issues related to preservation. Elsevier. http://www.journals.elsevier.com/journal-of-cultural-heritage

Masonry Institute of America. Technical Publications. http://www.masonryinstitute.org/products.php?catID=5

National Geologic Map Database. https://ngmdb.usgs.gov/ngmdb/ngmdb_home.html

National Research Council of Canada:
Canadian Building Digests series https://researchguides.georgebrown.ca/CBD
Construction Innovations series http://www.nrc-cnrc.gc.ca/ci-ic/
Construction Technology Updates series http://www.nrc-cnrc.gc.ca/ctu-sc/

Torraca, Giorgio. *Lectures on Materials Science for Building Conservation*. Los Angeles, CA: The Getty Conservation Institute, 2009. http://www.getty.edu/conservation/publications/pdf_publications/

US Department of Agriculture, Natural Resources Conservation Service, *Web Soil Survey*. http://websoilsurvey.nrcs.usda.gov/app/HomePage.htm

Date	Topics	Required readings before class	Other preparation before class
17 January Class 1 *Getting underway* *Building longevity* *Entropy: It is a law*	Introductions, course orientation, content Learning methodologies Artificial intelligence Student work product Performance evaluation Basic concepts in building longevity: Survival & loss, utility & use Obsolescence & adaptability Assets, liabilities, value Sustainability, Contexts 2nd Law of Thermodynamics Durability & service life	**Required Readings (available in Canvas):** Henry. HSPV 5510 Course Syllabus Henry, *Managing Collections Environments, Technical Note 1: Context and Use* Levin, *Preventive Conservation,* in *Conservation Perspectives* 7.1 Spring 1992 Brand, *How Buildings Learn*, Chapters 1-4, Chapter 10, Appendix. Watt, *Building Pathology*, Chapters 1-2*	**Submit** Self-assessment Current resume Complete *Namecoach* in Canvas **Lecture Slides** Henry. Lecture Slides Class 1 **Questions to reflect on** • How does Brand's diagram of shearing layers of change inform understanding of buildings? • What are examples of new forces that are changing buildings today? • What does "preventive conservation" mean when applied to immoveable cultural heritage?
24 January Class 2 *Systems thinking & visualization*	Thinking in Systems System structures Stacks, flows & dynamic equilibrium Feedback loops, types & effects System behavior Visualizing systems structure Visualizing systems behavior	**Required Readings (available in Canvas):** Henry, *Managing Collection Environments, Technical Note 2: Systems Thinking* Keene, S. A systems view of museums. In *Managing Conservation in Museums*. 2nd ed., 2002, pp. 79-96 Meadows, Donella H. *Thinking in Systems, a primer.* (pp. 1-72 & Appendix D) Tufte *Graphical Evidence* Minard's Chart of Napolean's March **Required Readings On-Line** • Notre Dame Fire: https://www.nytimes.com/interactive/2019/07/16/world/europe/notre-dame.html?searchResultPosition=1 **Optional Readings On-Line** • Champlain Towers South Condominium collapse: https://www.nytimes.com/interactive/2021/09/01/us/miami-building-collapse.html https://www.wsj.com/articles/behind-the-florida-condo-collapse-rampant-corner-cutting-11629816205?page=1	**Lecture Slides** Henry. Lecture Slides Class 2 **Questions to reflect on** • How does "systems thinking" apply to a diagnostic process for built cultural heritage? • What are the subsystems that comprise the Notre Dame fire event. What is the starting point in time for the event? **Optional** • What are the subsystems that comprise the Champlain Towers South collapse event. What is the starting point in time for the event?

Date	Topics	Required readings before class	Other preparation before class
31 January Class 3 *Problem Solving & Visualization* *Coincides with HSPV 5720 Preservation Through Public Policy DC trip*	Creative problem solving: Open ended & closed ended problems, problem definition, creative problem solving Visualizing information - a problem-solving tool: sketching spatial & temporal coordinates graphs, trendlines, tables & matrices Tufte's principles	**Required Readings (available in Canvas):** Tufte. *Visual and Statistical Thinking: Displays of Evidence for Making Decisions* Tufte. *Graphical Evidence* pp 14-52 Tufte. *Beautiful Evidence* pp 122-139 **Required Readings On-Line** *Thoughts on Problem Solving* https://websites.umich.edu/~elements/probsolv/index.htm (ignore examples that deal with chemical engineering) Creative Problem-Solving model http://members.optusnet.com.au/~charles57/Creative/Brain/cps.htm	**Lecture Slides** Henry. Lecture Slides Class 3 **Questions to reflect on** • Think of a problem you have recently addressed. Did you consider the problem in steps or phases, or did you go immediately to a solution? Did you think divergently, then convergently as you considered the problem? • What are Tufte's Principles? • How does visualization of information help in the problem-solving process?
07 February Class 4 *Diagnostic Thinking, Active Listening, & Seeing*	Diagnostic biases & traps Critical thinking: *Evidence & information gathering, analysis & conclusions* Active listening Seeing is knowing: *How we see, what we don't see & why* Qualitative Assessment: *Describing what we see, sharing what we've seen, terminology & visual glossaries, the repeatability problem* A possible diagnostic process	**Required Readings (available in Canvas):** Croskerry, P. *The Cognitive Imperative: Thinking About How We Think.* Academic Emergency Medicine 2000/7:11/pp 1223-31 Croskerry, P. *The Theory and Practice of Clinical Decision-Making.* Canadian Journal of Anesthesiology 2005/52:6/pp R1-R8 Croskerry, P. *Context is everything or How could I have been that stupid?* Healthcare Quarterly 2009/v12 special/pp 171-7 Bondreau, Cassell, Fuks. *Preparing Medical Students to become Attentive Listeners.* Medical Teacher 31 (2009) Aper, et al. *"Should I prioritize medical problem-solving or attentive listening…".* Patient Education and Counseling 98 (2015) Castelhano, Mack, & Henderson. *Viewing task influences eye movement control during active scene perception.* Journal of Vision 2009 9(3):6, pp. 1-15. Watt. *Building Pathology. Fig 5-13 Decision Tree for Diagnosis* Tufte. *Beautiful Evidence* pp 140-155	**Lecture Slides** Henry. Lecture Slides Class 4 **Questions to reflect on** • Are there parallels or similarities between active listening and careful observation? • What are examples of your own failure to see something in plain sight? • How will you apply what you have learned to observation of a building? • How can you make qualitative observations precise?

Date	Topics	Required readings before class	Other preparation before class
14 February Class 5 *Building Materials & Their Properties* *A brick is* *A brick is* *A brick…* *Or is it?*	Materials properties Quantitative & qualitative comparisons Archaic materials vs. modern materials Variability Properties of interest Design – Indicators of strengths Durability – Indicators of vulnerabilities Composite materials & assemblies Exercise: Identify materials by comparison of properties	**Required Readings (available in Canvas):** Henry, *NCPTT Technical Note: Materials and Older Buildings* Building Materials Properties and Units of Measure Melloy. Porous Building Materials Handout Harris, *Material Profile Charts – Brick, Steel, Wood & Blank* Watt, *Building Pathology*, Chapter 3 **Optional Resources:** Ching, *Building Construction Illustrated*, Chapter 12: Notes on Materials	**Lecture Slides** Henry. Lecture Slides Class 5 **Questions to reflect on** • How do the units of measure inform our understanding of the property? • Do some material properties have more than one unit of measure? Why? • How do you define material compatibility when selecting a replacement material in historic fabric? • Complete the blank Materials Property Chart by entering the *units of measure* for each of the properties. For which properties were units of measurement difficult to find?
21 February Class 6 *Air, moisture, & earth* *The stuff around the building*	The Psychrometrics of Air Temperature Moisture content Relative humidity Processes Climate & Climate Change Climatic impacts on heritage Systemic impacts of climate change Soils Composition Moisture capacity Classification Behaviors & effects on buildings Groundwater	**Required Preparation On-Line:** Psychrometric Chart tutorial – in depth with quiz https://www.uwsp.edu/papersci/Pages/charttut/story_html5.html **Required Readings (available on Canvas):** Beltran, *Managing Collection Environments, Technical Note 3: Psychrometric Processes for Environmental Management* Engineering Weather Data Handbook – short version Engineering Weather Data Philadelphia PA – short version Soils & Water Handout USGS, *Basic Groundwater Hydrology Water Supply (*pp. 1-15) **Other Preparation On-Line:** Go to the Web Soil Survey & learn about soil at a site of interest: http://websoilsurvey.sc.egov.usda.gov/App/HomePage.htm Watch: Water Movement in the Soil https://www.youtube.com/watch?v=ego2FkuQwxc Watch: Capillary rise in soil https://www.youtube.com/watch?v=5waNTa2b-yg	**Lecture Slides** Henry. Lecture Slides Class 6 **Questions to reflect on** • Do you understand the relationships of the properties of moisture vapor? • Do you understand what the NCDC climate data presents? (Read the NCDC Handbook) • Compare climate data for a city you are familiar with to data from an unfamiliar city. • Are you aware of climate change projections for you home city? • Do you know the properties & behaviors of the different soil types? • What is the fundamental difference between water moving in gravel & water moving through clay?

Date	Topics	Required readings before class	Other preparation before class
28 February Class 7 *Building physics* *"Follow the water"*	Building Physics Material structure Moisture & thermal energy transport in materials Thermal response Moisture transport & soluble salts Exercise: Africa House	**Required Readings (available in Canvas):** Straube. *Moisture, Materials and Buildings* Straube. BSD 138, *Moisture & Materials* CBD 130, *Wetting and Drying of Porous Materials* Lstiburek. BSI 011 "Capillary: Small Sacrifices" Melloy. *Heat Transfer Handout* Melloy. *Porous Building Materials Handout* Watt. *Building Pathology* Chap. 4, p. 114-119	**Lecture Slides** Henry. Lecture Slides Class 7 **Questions to reflect on** • Consider water & its molecular structure. How is this tendency manifested in the three regimes of moisture storage outlined by Straube? • Define hysteresis. What causes hysteresis in the movement of moisture in & out of a material? • What are the different transport mechanisms for thermal energy transport?
07 March Class 8 *Deterioration & Causality 1* *Goo & crud: How & why*	Overview of deterioration pathologies Necessary & sufficient factors Types of deterioration Combined or sequential mechanisms Synergies Biological Deterioration Microorganisms, vermin & critters Electrochemical Deterioration Corrosion Alkali deterioration of wood Ozone & ultraviolet light	**Required Readings (available in Canvas):** Watt. *Building Pathology*, Chapter 4, p. 96-114 Watt. *Building Pathology*, Chapter 4, p. 120-125 Watt. *Building Pathology*, Chapter 4, p. 130-137 Harris. *Building Pathology*, Chapter 2, p. 15-28 Harris. *Building Pathology*, Chapter 3, p.95-130 Meloy. Technical Note: "Biological Mechanism of Deterioration" Andrady, et. al., "Effects of Increased Solar Ultraviolet Radiation on Materials" Davis, *Corrosion: Understanding the Basics*, Chapter 2	**Lecture Slides** Henry. Lecture Slides Class 8 **Questions to reflect on** • Can a system diagram represent a deterioration mechanism & its necessary & sufficient factors? • What are the generalized necessary & sufficient factors for biological deterioration to occur? • How does the electromotive series influence how galvanic corrosion occurs? • How are ozone degradation & UV degradation related? In what ways are they different?
14 March	Spring Break NO CLASS		Relax/Learn/Catch-up!

Date	Topics	Required readings before class	Other preparation before class
21 March Class 9 *Deterioration & Causality 2* *Cracks & fractures* *How & why*	Mechanical deterioration Principal stresses Elastic versus plastic deformation Strain hardening, fatigue, creep & cracks Hygrothermal deterioration Linear & volumetric expansion/contraction Freeze-thaw Exercise: Estimating expansion & contraction	**Required Readings (available in Canvas):** Łukomski. *Managing Collection Environments, Technical Note 5: Physical Responses of Hygroscopic Materials to Climate* Harris, *Building Pathology*, Chapter 3, p. 58-95 CBD 047, *Extreme Temperatures at the Outer Surfaces of Buildings* CBD 056, *Thermal and Moisture Deformation in Building Materials* Stresses & Constraints Handout	**Lecture Slides** Henry. Lecture Slides Class 9 **Questions to reflect on** • Why is constraint/restraint an essential consideration in building assemblies? • What kinds of materials are anisotropic? How can anisotropy affect hygrothermal response? • Consider thermal, moisture, & stress gradients. Why are gradients important to understand & identify?
28 March Class 10 *Building Structures* *Loads & bones*	Building Structures Strength & stiffness Forces & loads Soils, groundwater & foundations Superstructures Types Performance deterioration Failures	**Required Readings (available in Canvas):** Blockley. *Structural Engineering: A Very Short Introduction* CBD 003, *Soil & Buildings* CBD 054, *Horizontal Deflections of Structural Members* CBD 148, *Foundation Movements* **Required Readings On-Line** Expansive soils https://www.youtube.com/watch?v=SW-NoiM726U&t=23s **Optional Resources:** Ching, *Building Construction Illustrated*, 1.30-1.33; 2.08-3.26; 4.02-4.40; A.06-A.07 Active statics: http://ocw.mit.edu/ans7870/4/4.461/f04/module/Start.html	**Lecture Slides** Henry. Lecture Slides Class 10 **Questions to reflect on** • What are the components of the three-phase system of soil? What are the important implications of this system with respect to building foundations? • Imagine you are in a historic wood-frame house. According to the L/360 rule for allowable deflection without cracking of finishes, how much is a 15-foot-long wood joist allowed to deflect? • Settlement typically occurs in two phases: immediate settlement & consolidation settlement. What are the differences? How do these two phases affect/cause differential settlement of a structure?

Date	Topics	Required readings before class	Other preparation before class
14 April Class 11 *Building Enclosures* *The external organs*	Building enclosure systems Static elements: roofs & walls Types of wall systems Operable elements Sash, shutters/shades & doors Energy efficiency improvements	**Required Readings (available in Canvas):** Straube, BSD 018, *Building Enclosures* Straube, BSD 011, *Thermal Control in Buildings* Straube, BSD 030, *Rain Control Theory* Straube, BSD 013, *Rain Control in Buildings* Lstiburek, BSI 117 *Rain Control in Walls* Lstiburek, BSD 106, *Understanding Vapor Barriers* Leslie, *Insulation with Vision* **Optional Resources:** Ching, *Building Construction Illustrated*, Chapters 5-7 Harris, *Building Pathology*, Chapters 3, 4, 5	**Lecture Slides** Henry. Lecture Slides Class 11 **Questions to reflect on** • Review the vapor profiles for the several types of wall assemblies laid out in Lstiburek's article. What might complicate these assemblies, i.e. how is the cladding connected to the structure? • Comfort is an extremely important consideration in how buildings function. What are the features of traditional enclosures that can be used to improve comfort?
11 April Class 12 *Building Systems* *The internal organs*	Building systems Comfort, climate & environmental Health & sanitation Fire detection & protection Information: security, data & communications	**Required Readings (available in Canvas):** Harris. *Building Pathology*, Chapter 6, p. 618-635 NPS. *Preservation Brief 24: Heating, Cooling & Ventilation in Historic Buildings* Straube. BSI-022 *Perfect HVAC* Lstiburek. BSD 109 *Pressure in Buildings* Padfield. *How Air Conditioning Works* Henry, *Managing Collections Environments, Technical Note 11: Non-Mechanical Environmental Management Strategies* Henry, *Managing Collections Environments, Technical Note 12: HVAC Options, New Constructions, and Microcontrol* **Optional Resources:** Ching. *Building Construction Illustrated*, Chapter 11	**Lecture Slides** Henry. Lecture Slides Class 12 **Questions to reflect on** • The importance of ventilation is clear with respect to moisture transport in wall assemblies. What are the negatives of having good ventilation? • What features do all utility systems have? Consider how these features could fail & the consequences of these failures, • Human thermal comfort can be affected by both physiological & psychological factors. How must we address this as climate changes?

Date	Topics	Required readings before class	Other preparation before class
18 April Class 13 *Sustaining Building Longevity*	Sustaining building longevity through reinvestment Exercise: Building Reinvestment **Course Review**	**Required Readings (available in Canvas):** Henry. *Technical Note: Building Reinvestment Model* Lstiburek. BSD 144, *Increasing Durability of Building Construction* CSA S478-95 *Guideline on Durability in Buildings, Appendix D pp 65-72* **Optional Resources:** Ching. *Building Construction Illustrated*, A.19-A.25: CSI Masterformat & ASTM Uniformat II	**Lecture Slides** Henry. Lecture Slides Class 13 **Questions to reflect on** • What costs does the Heritage Building Reinvestment Model not include? • Why does the Reinvestment Model not include these costs? • What are the terms used to define durability in buildings?
25 April Class 14 Test Interventions & Implementation	**Test of Knowledge** Interventions Setting objectives Identifying, evaluating & selecting preferred strategies Design for intervention & prevention Longevity & maintainability, reversibility Material & craft availability, costs Implementation Setting & achieving construction quality Follow-through, measuring efficacy	**Prepare for the Test** **Required Readings (available in Canvas):** Harris. *Building Pathology*, Chapter 1, p. 36-56 Watt. *Building Pathology*, Chapter 5 Brand. *How Buildings Learn*, Chapter 8 & 11-12 Henderson. *Managing Collections Environments, Technical Note 15: Negotiation and Consensus Building*	**Questions to reflect on** • How are the questions & tables that Watt presents helpful? How could they potentially be problematic given that each building is unique? • Harris' general categorization of intervention approaches is helpful; however, the interventions he discusses are really more like individual treatments. • Do Henderson's methods apply to cultural heritage conservation?
30 April	**Upload digital copy of Final Assignment and Self-Evaluation before 12 Noon EDT. No Extensions**		
16 May	**Grades due**		