Building Structure in the Context of Architectural Theory: A History/Theory Course on Technology in Architecture

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Abstract

Building technology is intertwined with the history of architecture. Through any cultural movement, architects chose an approach to the technical aspect of how a piece of architecture is constructed. Sometimes, this is simply an aesthetic approach to conceal or express. Often, it is more complex. Other times building technology is a key aspect in the development of architectural style. Engineers may not often consider this, as they are preoccupied with making technology work, not seeing it in the context of a greater, cultural expression. However, if we accept that, like art, architectural style is an expression of a *zeitgeist*, the treatment of building technology goes along with that spirit. This paper outlines a course in architectural theory that explores this idea – building technology as a part of architectural style – through a series of readings and discussions. The course surveys modern and contemporary architecture, from 1830 to present and looks specifically at how building structure is approached.

The instructor, a licensed architect and structural engineer, developed the course to broaden how both architecture and engineering students think about building technology and cultural representation. It is a course that focuses on ideas, not calculations, offering a Humanities credit and giving a new perspective to the work of engineers. Within this paper, the evolution of historical ideas that the course covers is described. The term "tectonic" is developed, along with its origins in the mid-19th century and its modern-day use. In addition, the role of the Industrial Revolution is discussed. Modernism relied heavily on technology, and the course looks specifically at building structure as part of this movement. After studying Modernism, the course also looks at Postmodernism, which is typically viewed as an antithetical to the tectonic ideal. The last few weeks of the course explore late 20th and 21st century writings and engineers, such as Kenneth Frampton, Neal Leach, and Cecil Balmond. The paper also outlines the course structure, as well as teaching strategies and academic goals. The topic lends itself to lively discussion, as many times topics to not contain a "black-and-white" answer, however motivating students to engage in such discussion is essential to its success.

Keywords: Architectural Theory, Structures, Course Development, Student Writing, Tectonics, Tectonic Theory

Preamble

In 1831 Victor Hugo made the dramatic historical declaration, "Printing will kill architecture." He was no architectural historian. Additionally, he was writing in hindsight, almost four centuries *after* the invention of Gutenberg's printing press. Yet, he asserted regarding that moment in history: "…the book of stone, so solid and so durable, was about to make way for the book of paper, more solid and still more durable."[13] He was, of course, reflecting on architecture as a tool for communicating societal ideas with the masses. Once the permanent, timeless record of the ages, reflecting culture and values, communicating the message for all manner of powerful figures of civilization – architecture would never have the same potent power of messaging once it was eclipsed by the far-reaching extents of the

written word. In a way, Hugo was right: architecture was never the same after that historical event. In a way, however, he was wrong: the communicative power of architecture did not die. Architecture to this day carries symbolic power, and can be studied as a timeless expression of cultural ideas and values.

A course on history and theory of structures in architecture

Victor Hugo's nineteenth century assertion is the opening topic of discussion in the newly-developed History Theory of Structures in Architecture course, offered in the Spring semester of 2021 in the Oklahoma State University School of Architecture. The purpose of this discussion, which has relevance today as we enjoy the multitude of media capable of communication, is to prompt students to recognize the role of architecture as a vehicle to transmit ideas of societal significance. This is a discussion of representation – and can apply to many disciplines of art. Architecture, however, stands out as it is inextricably tied to economy and typically requires an enormous amount of collaboration from designers, engineers, and contractors. Once students accept architecture's cultural significance, the discussion then turns to the role of technology, specifically structural engineering, in the development of architectural form and aesthetics. This is not inconsequential; as the course continues students explore this theme of the relationship between structures, architecture, and cultural expression. As Edward Ford noted in *The Details of Modern Architecture*: "…. architectural technology is no more objective or subjective than architectural design, and that an architect's relationship to the building conventions of his time usually mirrors his relationship to the rest of society."[6]

The course content develops this idea by briefly discussing Gothic architecture (the object of admiration as expressed by Victor Hugo) then looking at architecture history and theory in the 19th century to present. The connection to engineering is not a difficult one to make for this time period. The 19th century is filled with architectural writings seeking a style and a means to use the newly developed iron technology, which eventually evolved to modern-day steel. The early 20th century brought the development of reinforced concrete. With these advancements came a new way to design and a new aesthetic of representation.

This pivotal role of technology can be seen in the amount of discussion dedicated to the topic in both Sigfried Giedion's *Space Time and Architecture*[12] and Peter Collins' *Changing Ideals in Modern Architecture*[4]. These heavily-relied on texts of architectural history extensively highlight the role of engineering during this time period. Gideon does so mainly in "Part III: The Evolution of New Potentialities," which discusses the role of iron and the development of the steel frame. Further, Gideon goes on to illustrate the new building technology in "Part IV: The Demand for Morality in Architecture", wherein the idea of 'honesty' in expression of building systems is discussed, as well as the development of reinforced concrete. "Part V: American Development" explores many topics, but uses construction technology as a starting point for many of these discussions. Collins' book follows the narration of structural engineering technology in architecture in the chapters "The Demand for a New Architecture," "The Mechanical Analogy," The Influence of Civil and Military Engineers," and "Rationalism." For further reading on twentieth century architecture, Reyner Banham's *Theory and Design in the First Machine Age*[2] is also a great resource.

Students in this course include Architecture and Architectural Engineering majors, who enroll to fulfill an "H" (Humanities) credit. Enrollment in the pilot semester had a large percentage of Architectural Engineers, as

the subject matter obviously connects their chosen major to a broader significance within the realm of humanities. Architecture students within the class enthusiastically embraced discussions on technology, considering impact on design process, form, and aesthetics.

The thread of representation and structures in modern architectural history

The following section discusses the development of architectural theory, beginning in the 19th century, providing a survey that acts as an outline for the course content. These topics are explored through the vantage point that structural evolvements were essential to the development of architectural style. As historical works and events are discussed, connections are made to larger themes, which are noted herein.

As mentioned, Gothic architecture is briefly discussed, as it serves as a prime example for an instance in architectural history wherein structural innovations transformed the built environment. As Victor Hugo asserts, it is a time where the entity in power (the Catholic Church) communicated its power as well as the awe of the Divine through the architecture of cathedrals. In this architectural style, structural innovations such as the flying buttress and the pointed arch allowed these buildings to manipulate old notions of proportion to make grand volumes of space, filled with light. Structurally, a distinct shift can be seen from supports of load-bearing walls to more columnar supports. There were no formal engineering calculations, and mistakes were made; limits were pushed to the point of collapse, then rebuilt until the structure worked. When the class was asked “Is this structural engineering?” one savvy student answered “it’s the research phase of structural engineering.” Themes discussed during this portion of the class include the idea that architecture may be used to communicate ideas, and also may be seen as a symbol for its cultural or temporal context.

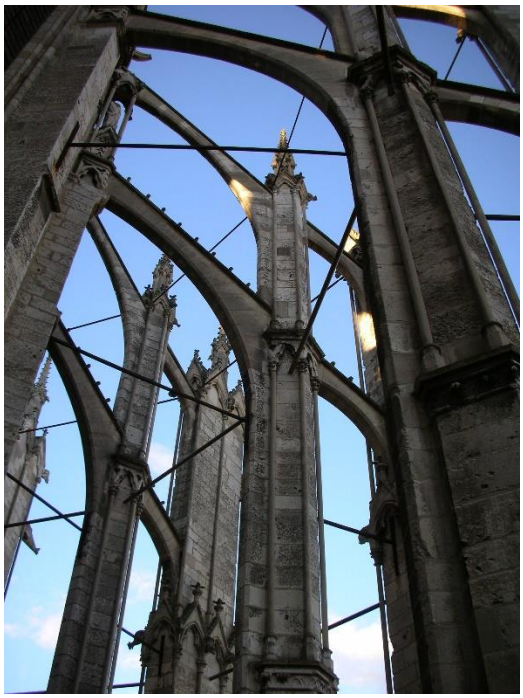

Figure 1: Beauvais Cathedral buttresses and reinforcement, Accessed May 3, 2021, https://phys.org/news/2014-12-gothic-cathedrals-blend-iron-stone.html

Nineteenth-century Europe saw a series of debates on style. The eclecticism of the period included revivals in the Gothic style, as well as Neo-Classicism. With these debates, however, also came a demand for a new “style,” one that reflected new building technologies. Viollet-le-Duc led this discussion in France, speaking out for Rationalism, an architecture that expresses the constructional basis of building and rejects a historical basis for aesthetics and form. Viollet-le-Duc’s writings, which include *Entretiens Sur L'Architecture*[22], warn of the deleterious effects of a “split” between architecture and engineering. Class discussion for this time period explores the theme of “honesty” in architecture, as well as the relationship between architecture and engineering.

Contemporaneously in Germany, the architectural theorists Gottfried Semper and Karl Bötticher were developing similar ideas. Both spoke of "tectonics" in architecture – a term that has persisted in the background of discussions of structures in architecture throughout modern history. Semper, in *Four Elements of Architecture*[18], talked of the basic units of dwelling: the mound, the hearth, the frame, and the enclosure. These elements, which are imbued with ephemeral meaning and symbolism, connect architecture with a constructional basis. Semper also writes with a preoccupation for joinery and weaving, making many analogies to building in his *Bekleidung* theory. Bötticher, who comes from an archaeological background, discusses the separation between the "art-form" and "core-form" in building, a notion that remains a key concept of tectonics in architectural theory.[3]

Discussions on these theories and ideas concerning style take place in the backdrop of the industrial revolution. Architects are aware of the development of iron as a building material, but are slow to adopt it, as they are unsure of how to treat it aesthetically. Thus, iron saw its beginnings in structural use in bridge design, a venue uncomplicated by the theories of architectural style. Then, humbly, iron found its way to factories and warehouses. Then, storefronts. The first large-scale use of the material is famously the Crystal Palace in England. This building is not so much regarded as significant for its aesthetics as it is for its design and construction process. The Crystal Palace showed the world the advantage to modular, grid-based construction, wherein a building can be assembled as a kit of parts when using a standardized dimension system and iron fabricated off-site. The exhibitions of Paris in the late nineteenth century were a showcase for iron, making way for a new style based on this building material. A course theme discussed alongside these topics is the use of technology as a catalyst for architectural style.

Figure 2: Hulton Archive/Getty Images, Accessed May 3, 2021, https://www.britannica.com/topic/Crystal-Palace-building-London

The Modernism of the early 20th century fully embraced a style that centered around a new building technology. As iron evolved to steel, the American skyscraper was born. In addition, engineering development turned its focus to reinforced concrete, a material that enjoyed a cmuch quicker acceptance than its ferrous counterpart. The story of architectural Modernism has magnanimous characters with confident manifestos – a fun subject to study indeed. Le Corbusier embraced reinforced concrete, using it rough, unpredictable surface in contrast with its polished version. Mies van der Rohe was equally prolific in his use of steel: examples of Crown Hall and the Barcelona Pavilion show his rejection of historicist architecture and his love of an architectural aesthetic that showcases its technological basis. Echos of Semper's fascination with joinery can be seen in Frank Lloyd Wright's architecture, and later in the work of Louis Kahn.

Figure 3: Crown Hall, Accessed May 3, 2021, https://arch.iit.edu/about/sr-crown-hall

Figure 4: Duran, Virginia, "Fountain Detail, Accessed May 3, 2021, https://virginia-duran.com/2013/03/07/architecture-modern-monumentality-louis-kahn/

In contrast, the late 20th century saw a shift away from a structural aesthetic. Despite excellent examples of collaboration such as the Pompidou by Piano, Rogers, and Rice, many architects became interested in the ideas of Postmodernism. Venturi et. al.'s *Complexity and Contradiction in Architecture*[21] and *Learning from Las Vegas*[20] are resources used to explore these ideas, which are often unconcerned with construction and structural engineering. Class discussion here returns to the theme of architecture as a medium of communication, but reframes this idea in the context of the postmodernists' point of view.

As the pendulum swung, however, a reaction to postmodernism yielded a renewed interest in tectonics, as Kenneth Frampton;s 1990 essay "Rappel l'Order"[7] called for a return to the notion of tectonics in architecture. Frampton urged a consideration based on his experiential approach to architecture, where physicality and materiality are valued. Other sources, such as Frascari's "Tell-the-Tale Detail"[11] and Leach's "Digital Tectonics"[15] explore these themes in a contemporary context. Finally, a survey of the work of Cecil Balmond examines a process-based approach to design, where structures become a major generator of form. Several larger themes can be extracted from these topics: the relevance and meaning of tectonics in today's architecture, the analogous relationship of the incorporation of digital technology in architecture to other technologies, how the interaction of society in a digital realm may have repercussions on the importance of architecture, and what emergent design may mean to the future of structures in architecture.

Course structure

The course is designed to focus on ideas, not solely memorization of architectural works. As such, it is set up to include a great deal of discussion. Student assessment is based on the following exercises:

Student-Led Discussions: Each week a different reading is assigned. Reflections and conclusions from this reading are discussed in class in a colloquium format. Each week a different student develops an agenda and a minimum of three discussion questions for the class. The agenda and questions are printed for class distribution. In addition, they are posted online in the class learning management system at least two hours prior to class, so that students may review and feel prepared for discussion. Discussions occur in-class prior to the professor-led lecture. The grade for this portion of the class assesses both the student's

leadership in his/her assigned topic session, evaluation and insight to the assigned topic, and participation in all sessions. See **Appendix 1** for a sample list of student readings from the Spring 2021 semester.

Student Reflections: At three points during the semester, students are asked to write a 2-page reflection on the course content thus far. Writings are assessed based on grammar, spelling, clarity of thought, and organization. Feedback is provided, and students are expected to show improvement over the semester.

Quizzes: Students' understanding of key concepts are assessed throughout the semester by periodic, scheduled quizzes.

Final Paper: At the end of week 2, each student is asked to select a significant work of architecture or the body of work of a particular architecture firm as the subject of a research paper. The paper should outline how concepts from class relate to the work(s) of architecture. Papers have a minimum of 10 pages.

Final Exam: The final exam for this course is comprehensive and a mixture of multiple choice, short answer, and essay questions.

Students are encouraged to do the reading and participate in discussions for a few reasons. First, the instructor challenges them at the beginning of the semester to open their mind to this type of learning, as most of their coursework is studio-based or technical classes. In addition, the instructor points out that there are no tests over the development of the semester, so putting effort into the reading is a sort of exchange. To supplement this skill, the instructor goes through the initial reading, "This Will Kill That," in class and demonstrates practices of highlighting and taking notes on key points. Since classmates are leading the discussion, a reminder is also given to be a "good classmate" by participating in the discussions that are peer-led. Finally, during discussions, the instructor makes a point to take notes and record who is participating along with their ideas.

Student reflections are a way for the instructor to give feedback on writing style and mechanics over the course of the semester. The two-page format is a manageable size for students to reflect on course topics and give the instructor a "pulse-check" on comprehension of concepts.

The final paper is a major focus of the class. As such, intermediate deadlines are given to keep students' focus. Deadlines include: selecting a topic, drafting an outline, creating a paper draft, and the final paper submission. The instructor schedules one-on-one conferences following the paper draft and final paper. These conferences have been very positively received by the students; getting one-on-one feedback and attention serves as a motivator for the quality of their work. Some students struggle with striking the right balance between personal analysis and the inclusion of historical facts, and the conferences aid to coach students through that difficult skill.

Course outcomes and student work

Topics of technology in architectural process, form, and aesthetics are discussed from various viewpoints, with students drawing personal conclusions along the way. Within this scope, major themes that surface include the "split" between architects and engineers, the use of new technologies in the generation of architectural style, the relationship between structure and skin, and the relevance of the notion of tectonics in building today. Concerning the split between architecture and engineering, one student grappled with a class example

to expand on the outcome of different design approaches:

"In the case of the St. Pancras Terminal, the disjointed architecture is caused by engineers working on certain parts of the terminal and architects working on the hotel connected to it, resulting in a hodgepodge of design. The engineer's approach was the iron truss vault system creates the roof of the terminal. The architect's hotel's design utilizes brick and stone as the main materials. One could say that if the iron truss vault dictates the design of the terminal, the hotel is the opposite where the form dictates [the construction material]."

Figure 5: St. Pancras, History, St. Pancras International Terminal, Accessed May 3, 2021, https://stpancras.com/history

Drawing an analogy to how structural innovations have impacted the evolution of architectural style, one student discussed parametric modeling and cross-laminated timber as technologies that are evolving and changing architecture:

"…it is more important than ever that we, as the community that designs and builds the spaces that significantly affect the experience that people have within buildings, keep up with the race that is new technology. New technology in this case also includes new materials. Although new materials and new design technologies can be daunting and expensive, revolutionary designs come from evolutionary steps. It is easy to continue to practice what you know and are comfortable with but if architects do not accept these new ideas, they are bound to get left behind by people that will. "

One student reflected on the relationship of structure and skin:

"This separation of structure and skin makes many things possible that were not before. Since we started hiding that steel structure with an exterior skin, it became easy to hide other things in the walls as well. We stick all kinds of things in with the bones of our buildings, they now have entire systems of neurons organized in the electrical work and a set of lungs that keeps HVAC continually flowing. These are all amazing things that this new method of building has made possible, all neatly stored in a space that used to be filled with stone."

In a broad sense, students of the class are prompted to consider architecture as a medium of expression for cultural ideals. Further inquiry considers the relationship of building structure to this architectural expression. This structure is a necessity to any built piece of architecture, but the aesthetic approach and design consideration of it varies throughout cultural history. The discussions surrounding structures in architecture can be extrapolated to look at various forms of technology: material, computational, etc. There's also an implicit suggestion that the process of architectural design is in its own way a reflection of the

cultural context. As future designers of the built environment, students are led to the recognition that the aesthetic medium of architecture cannot ignore technologies in its pursuit of cultural expression.

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Appendix 1: Weekly course readings from Spring 2021

[1]	250 Things an Architect Should Know (Sorkin, 2020)
	Executive Order on Promoting Beautiful Architecture (White House Exec Order, 2020)
[2]	“This Will Kill That” in Hugo (Hugo 1888)
[3]	Excerpts from Hearn *The Architectural Theory of Viollet-le-Duc* (Le Duc, Hearn 1990)
[4]	“Structure, Construction, Tectonics” in Kepes (Kepes 1965)
[5]	“Introductions: Reflections on the Scope of the Tectonic” in Frampton (Frampton 1995)
	"Construction" in (Wagner, 1988)
[6]	“Technical transformations: structural engineering 1775-1939” in Frampton (Frampton 1980)
[7]	“Structural Rationalism and the influence of Viollet-le-Duc: Gaudi, Horta, Guimard and Berlage 1880-1910” in Frampton (Frampton 1980)
[8]	“The Mechanical Analogy” in Collins (Collins 1965)
	“The Engineer’s Aesthetic and Architecture” in Le Corbusier (Le Corbusier 1946)
[9]	“Introduction” in Ford (Ford 1990)
[10]	“A Significance for A&P Parking Lots, or Learning From Las Vegas” (Venturi, et al)
[11]	“Rappel a L’Ordre: the Case for the Tectonic” in Frampton (Frampton 2002)
[12]	“Aesthetics of the Spatial Function” in Sandaker (Sandaker 2008)
[13]	“The Tell-the-Tale Detail in Nesbitt (Frascari 1996)
[14]	“Digital Tectonics” in Leach (Leach, Turnbull, and Williams 2004)
	“Design by Algorithm” in Leach (Leach, Turnbull, and Williams 2004)
[15]	“Introduction” and “Manifesto” in Balmond (Balmond 2001)