HISTORY OF TECHNOLOGY AND PRESERVATION ENGINEERING

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Introduction

The title of this discussion topic reveals a split in the material that effectively creates two topics. The history of technology, with all the possibilities it includes for improving our understanding of the existing built environment, is ultimately a field concerned with the past. In short, it is a sub-set of history and other social sciences. Preservation engineering under any of its many names, including conservation engineering and heritage preservation technology, is a field concerned with the present. A practitioner of preservation engineering evaluates and conserves existing structures, or teaches others to do so. As a subset of engineering, this work has as a goal present and future safety. The relation between the two fields is obvious, in that engineering work with existing buildings often requires knowledge of the history of some particular building technologies, and that history of technology serves the practical purpose of helping to explain why and how the existing buildings were constructed.

Both of these broad topics include many sub-topics. The history of technology, as applied to structures, includes among other topics the development and industrialization of traditional materials such as wood and brick, the industrial development of iron and steel, the development of essentially new building materials such as aluminum and reinforced concrete, development and industrialization of construction-site practices such as excavation and hoisting, and the organization of design and construction. A popular history of construction such as David McCullough's *The Path Between the Seas* includes discussion of transportation of excavation spoil, changes over time in excavators, and methods of placing concrete. (McCullough 1977) An academic history such as Amy Slaton's Reinforced Concrete and the Modernization of American Building, 1900-1930 includes sociological discussion of the creation of experts, taylorism, and definition of new types of labor along with more mundane topics such as field testing of concrete and the standardization of specifications. (Slaton 2001) In this paper, the history of technology is of interest when related to building design and construction, including the creation of constituent materials and site work. This portion of the broader history of technology is less well-developed than the overall field is. Specifically, the history of non-industrial design (such as building design) and unique or near-unique fabrication (such as construction of individual buildings) is less researched than industrial design and manufacturing.

Preservation engineering has sub-topics that reflect the divisions with ordinary engineering, including the distinction between structure and mechanical systems, forensic analysis, preservation (in ordinarily engineering terms, "repair") design, alteration design, and upgrades for seismic compliance and other modern concerns. These sub-topics are studied and understood to wildly different degrees. At one extreme is the preservation of obsolete mechanical systems such as gas-lighting: since these systems are not used in modern building and usually do not meet modern code requirements, they are either removed from existing buildings, abandoned in place, or replicated in more modern forms. At the other extreme is the repair of early steel frames: since the standards and materials are closely related to modern standards, the repair methods used are often indistinguishable from those used for newer buildings that are considered non-historic.

State of Knowledge

The history of technology as it relates to buildings falls between several well-defined fields, none of which contains it fully. For example, the introduction of iron and steel into buildings has been considered by architectural and technological historians; conflicts between new professions and bureaucracies have been discussed in political and social terms, and the influence of new technology on society has been discussed in the context of adaptations to modernity, but none of these subjects includes the discussion and use of new building technology.

Histories of technology, whether traditional linear narratives of progress through heroic effort or more recent analyses of the social construction of technology, usually focus on machines and processes rather than large, static buildings. Thomas Hughes's *American Genesis*, for example, is a history of technological change between 1870 and 1970 and updates the great-man technical histories by including social context, using as examples the famous independent inventors of the late nineteenth century – Edison, Bell, Tesla, Thomson, and the Wrights – and their successors in the research and development labs of the twentieth century. Hughes defines “the technological world, the world as artifact”: it was that created by “a nation of machine makers and systems builders.” (Hughes 1989: 1) David Nye’s *Narratives and Spaces*, by contrast, is a description of social construction of the technology of modern America and focuses on civil works such as rural electrification, twentieth-century World’s Fairs, and the Apollo program. (Nye 1997) Robert Pool similarly describes the social shaping of technology using examples of electrification, nuclear power, and private cars. (Pool 1997) The machine and system emphasis helps differentiate technology from everything else; even historians of technology trained as engineers or scientists have to explain the concepts to those with little knowledge, an effort aided by a clearly defined object. Building technology has fuzzy boundaries because it includes hand-tools and heavy industry, buildings of all sizes and uses, hundreds (if not thousands) of years of rules and traditions, and testing and development through public use.

Works in the relatively new field of philosophy of technology often contain discussion of the place in society for technology or engineering, but as forward-looking theoretical analyses. For example, Billy Koen’s discussion of engineering problem-solving uses epistemological and logical tools to analyze “the engineering method.” Koen devotes several pages to the issue of the “Engineer and Society,” discussing problems in applying only engineering logic to problems with societal consequences. He does not, however, give a single example from before 1990, nor does he give any reason why historical problems might be of interest. (Koen 2003: 53-56)

Architectural history has traditionally included the technology of construction, but has done so in a reductive, deterministic fashion. Before the 1950s, architectural history was dominated by stylistic descriptions and geometric analysis of buildings or individual rooms within buildings; later histories greatly expanded the field by including social influences on design and the effect of buildings on society. Even comprehensive and influential architectural histories focused on technology, such as Sigfried Giedeon's *Space, Time, and Architecture*, discuss the effect of new technology on architectural design, not the methods by which new technology was adopted into construction. (Giedion 1967) This is, of course, the architects' view: since the new technology discussed here was introduced by builders and engineers, it came from outside the ordinary experience of architects. The traditional view of new building technology use as invention is represented by a 1961 description of the Home Insurance Building in Chicago as "the world's first completely articulated, multistory 'steel skeleton clothed in a nonstructural [masonry] skin." (Fitch 1963: 221-233) This is factually incorrect from an engineering perspective, as the building frame used cast-iron columns, not steel, and the frame was not a skeleton type, where the exterior wall is supported by the metal elements. Classics of urban history, such as Schlesinger's *The Rise of the City*, are forced by the nature of broad-review writing to limit discussion of any topic, for example reducing the development of steel framing to a few sentences: "Less bound by tradition than Boston or even New York, it was Chicago, only recently risen from its ashes, which discovered the solution. This was the use of iron or steel for the support of floors and walls, thus reducing the masonry to a thin veneer...” (Schlesinger 1933: 282)

Architectural history is now often combined with social history, as in the essays that make up Ward and Zunz’s *The Landscape of Modernity*. (Ward and Zunz 1992) Most of the essays focus on housing or urban planning, but four specifically look at the transformation in architecture enabled by new construction technology and the social context of those changes. Keith Revell’s and Marc Weiss’s essays discuss the multi-party conflict over construction density and political campaigning that resulted in New York City’s 1916 zoning law as well as the effect of the law on architectural design; while they capture the complexity of negotiations between real estate, governmental, and professional interests, he does not address the technology that made the physical changes possible. (Revell 1992; Weiss 1992) Gail Fenske and Deryck Holdsworth’s, and Carol Willis’s essays discuss the economic background to the creation of the skyscraper boom before the 1930s Depression, but technological issues in the design of skyscrapers are omitted from the discussion of real estate pricing, zoning, and architectural design. (Fenske and Holdsworth 1992; Willis 1992)

Recent works include studies of the organizational context of the physical manifestations of modernity. *Building Gotham,* Keith Revell’s description of the politics and planning of creating the water, sewerage, and rail infrastructure of Greater New York comes closest to the topics of interest but focuses on large systems. It can be argued with some validity that water and transportation systems were more central to the development of modern cities than building technology, since major European cities continued to use building technology more primitive than that in New York but used similar or more advanced infrastructure. For example, steel skeleton construction was not legal in London until 1909, at which time New York had hundreds of tall steel-framed buildings, and was slow to come into use after then. A difficulty in this type of study is that the government bureaucracies and other organizations described had been active earlier with smaller-scale technologies, such as those employed in individual buildings. Revell's statement that "experts from various disciplines provided those generalizations [of solutions to common problems] in key policy areas, each with its own history, its own timing regarding the creation of administrative mechanisms, and its own institutional context within the city, state region, and nation" is on target, and the actions of the various experts simply need to be detailed for any given problem concerning both technological and social issues. (Revell 2003: 14)

A few monographs have touched on specific aspects of the larger topic. Discussion of government positions on building technology and building codes has been limited; the only scholarly work that covers the full breadth of this topic for any location and an extended period of time is John Comer's *New York City Building Control, 1800-1941*, published in 1942. (Comer 1942) While it includes all of the technical advances of interest, it is now badly dated in terms of its discussion of architecture, engineering, and urban development. More recent studies have focused on only one aspect of codes and government control, such as Sara Wermeil's *The Fireproof Building: Technology and Public Safety in the Nineteenth-Century American City*, which provides a great deal of information on fire protection in codes and construction, but little context. (Wermeil

2000) It should be noted that building codes are one of the neglected areas of the history of technology that have had an immediate effect on the technologies used.

There are organizations and journals dedicated to the history of building technology. For example the Construction History Society, well established in Britain and with an American branch created in 2008, specifically addresses issues in the history of technology as applied to the design and construction process. There have been two international conferences on the history of construction, in Madrid in 2003 and Cambridge (UK) in 2006; a third will take place in Cottbus (Germany) in 2009. The journal of the CHS, *Construction History*, advertises itself as “the only English-language periodical on the subject.” A parallel set of international engineering conferences has been held until the title “Structural Analysis of Historic Construction,” with the most recent in Bath (UK) in 2008. These conferences and their published proceedings clearly show the more advanced state of preservation engineering and the history of building technology in Europe as compared to the United States.

Since there are no formal education programs in preservation engineering, the state of knowledge can best be judged by the existing mechanisms for knowledge transfer: informal training, short courses and other non-accredited education, and organizational activity. The SAHC conferences and the establishment of an engineering technical committee within the Association for Preservation Technology International are examples of organizational activity that does not have a constant presence but regularly brings together groups of people interested in the field. On-the-job training of young engineers and project-oriented research conducted for engineering projects cannot be directly measured but can be said to be universal in the field since all practicing preservation engineers have been trained this way. Finally, the APTI and similar organizations sporadically offer short courses, usually for continuing education credits, in the form of one-day workshops attached to the general annual meeting.

In short, the split between the state of knowledge for two topics can be defined thus: history of building technology has an established literature base that stands partially on its own and partially subsumed within other, better-known fields such as architectural history and the history of industry, while preservation engineering is largely a *de facto* specialty for a self-selected group of designers and contractors.

Various issues need to be addressed in both topics. The effective division of the history of building technology from the history of technology has allowed interested parties to pursue and advance the history of building technology, but has limited interaction with the broader currents in historical thinking. If it is possible to better integrate disparate organizations such as the Society for the History of Technology and the Construction History Society without eliminating the smaller, more specialized CHS, this would be to the advantage of building historians. In the case of preservation engineering, the need is simpler: the field is not well known, ill defined, and often considered expendable. Research and training in the specific fields of knowledge required for preservation engineering – including the general history of engineering and construction, the history of analysis methods, a chronology of construction materials and systems, methods of analyzing buildings other than skeleton frames, and methods of field investigation of existing structures – must be made known to the general engineering community for better recognition and must be made known to all members of the preservation engineering community who do not all have access to equivalent levels of knowledge.

State of the Field in Practice

Knowledge of the history of technology and preservation engineering is not required for the practice of engineering and construction. The legal requirements are a state-issued license ("professional engineer" or "registered architect") for design and usually a state or local contractor's license for construction. There is therefore no bar to any licensed designer or contractor working on preservation projects regardless of their training. Knowledgeable owners may address this problem through pre-qualification requirements in project requests for proposals and requests for bids; knowledgeable designers may address it through pre-qualification requirements in project specifications.

In recent years, there has been a movement to create subdivisions among professional engineers through secondary licensing or specialty certification. ("Report," 2002) To date, only the most common specialties have been addressed, for example by the "structural engineer" license that can be attained after the professional engineer license in several states and the non-statutory credential of the Structural Engineering Certification Board ("SECB History," 2009) Given that the requirements for structural engineering as a subset of professional engineering are generally agreed upon, based on more than one hundred years of curriculum development and nearly one hundred years of licensing, and the definition of preservation engineering is still open to debate, it is unlikely that statutory recognition of preservation engineering will occur in the near future. It is possible that self-certification within the field, similar to SECB, could be achieved. For example, the Preservation Engineering Technical Committee of the APTI has "identify and undertake initiatives to advance the role of the preservation engineer and an understanding of the importance of preservation engineering" as one of its critical tasks, and the members of the committee have discussed the possibility of certification. ("APT Technical Committees," 2009) The task is a difficult one that requires more effort than a small organization such as the APTI committee can provide alone.

The history of technology is ultimately academic and is rarely addressed as such in practice. The reason is clear: the people dealing with an existing building through investigation or design are necessarily most concerned with the physical object of interest. The method of steel production, for example, is of less interest in analyzing a beam in an 1890s building than are the chemical and mechanical properties determined through testing. While knowledge of the production method may provide insight into the properties, the testing is still required and therefore makes the historical knowledge optional. A practitioner needs a basic education in the history of technology – one that is not required by any graduate or undergraduate engineering education in the United States – to recognize conditions in historic buildings that are outside the scope of modern engineering. Any engineer working in preservation and many owners of historic buildings and architects can tell stories of fixing gross errors made by engineers who, despite their competence in structures, had no understanding of buildings with pre-modern systems. At this time, given that there are no licensing or certification programs and given that collegiate education for preservation engineers is still in its infancy, the historical knowledge required is typically learned on the job.

Preservation engineering as a field includes many engineering skills not related to the history of technology, such as choosing analysis methods appropriate for the structure at hand. (Friedman, 2001) Modern analysis relies heavily on matrix methods performed by computer, the common use of which post-dates historic buildings. Older methods, including in reverse chronological order moment distribution, cantilever and portal frame analyses, and graphic statics are mostly taught in summary or neglected. These methods are valuable in reverse-engineering an existing building to better understand the original design. Similarly, structural elements that are now rare, such as true masonry arches, are largely neglected in current engineering curricula. Other skills that an engineer may need in preservation work are identical or closely related to those in mainstream work, including the methods for conducting a field investigation.

Finally, as mentioned in the "Introduction," structural engineers take far more interest in preservation engineering than mechanical engineers. Historic structures are far more likely to meet modern standards as is, or with realistically small interventions than are historic mechanical systems. Standards for HVAC, lighting, and plumbing have changed considerably since 1900, and more so before that date. Historic buildings typically need to be upgraded with modern plumbing, lighting, convenience electric outlets, and heating systems to remain viable for use. The few exceptions are often house museums and similar buildings where modern usage is unimportant and historic atmosphere must be maintained.

State of the Field in Education

The treatment of the two topics under discussion in formal education could not be more different. History of technology is recognized as a field of study at both the undergraduate and graduate levels, either as a stand-alone topic or as part of a “Science and Technology Studies” program. As such, it is part of ordinary collegiate life including standardized curricula, scholarships and fellowships, and dedicated professorships. (for example, Georgia Tech 2009) In itself, the field is accepted as a part of academia and needs little change. On the other hand, preservation engineering, as such, is not taught as an academic subject in the United States. The current opportunities for students are therefore limited to co-op jobs and similar practitioner internships, and tangential work such as Historic American Engineering Survey documentation surveys.

To establish preservation engineering as an academic subject will require boot-strapping: until at least one program is operating, there is no impetus to create standard criteria for establishing curricula or to provide research opportunities on a regular basis. The basis for a program may be found in existing efforts, such as the course modules developed by Michael Henry and Sam Harris with a grant from the National Center for Preservation Technology and Training, which were expanded from a two-day workshop at an APTI conference to a two-week short course offered at the NCPTT. (Ferrell 2007) The modules were Materials and Older Buildings, Building Pathology, Investigations and Diagnostics

Methodology, and Treatment Strategies and Interventions. Obviously, there is overlap between this material and ordinary engineering courses, but the value in these course modules lies in their emphasis on the preservation field. These four topics define, in very broad terms, the areas that a competent preservation engineer must know.

The NCPTT/Henry and Harris modules are available to institutions that wish to host short courses and could serve as the basis for a collegiate curriculum at the masters level. A full undergraduate curriculum would be difficult to develop as it would require students to learn all of the material of an ordinary structural engineering student as well as the additional material for preservation. Given the crowded state of undergraduate engineering curricula, adding more courses is not possible unless they replace existing electives. The possibility of adding one or two undergraduate courses as electives should be explored.

Funding for preservation engineering education will depend on the success of integrating it into collegiate education. As long as the field is dominated by preservation organizations, where engineers are inherently a minority and money is generally scarce, funding will be limited to grants from non-profit organizations such as the NCPTT and the The James Marston Fitch Charitable Foundation. The larger grants available for engineering students and education projects from sources such as the National Science Foundation would become available for students and faculty associated with a formal course of study.

Bibliography

"APT Technical Committees" Association for Preservation Technology International. http://www.apti.org/about/technical.cfm accessed March 1, 2009.

Comer, John P. 1942. *New York City Building Control, 1800-1941*. New York: Columbia University Press.

Fenske, Gail and Holdsworth, Deryck. 1992. "Corporate Identity and the New York Office Building: 1895-1915" in Ward & Zunz, *The Landscape of Modernity*.

Ferrell, Andrew. May 2007. "Engineering Issue and Historic Buildings," in *The Louisiana Civil Engineer.* 5-7.

Fitch, James Marston. 1963. "Skyscraper: Skin For Its Bones," *Engineering*, Samuel Rapport and Helen Wright, eds. New York: New York University Press.

Friedman, Donald. July, 2001. "Methodology of Conservation Engineering," *Journal of Architectural Conservation*. 49-63.

"Georgia Tech School of History, Technology, and Society: Graduate Programs" http://www.hts.gatech.edu/graduate/phd.php accessed March 1, 2009.

Giedion, Sigfried. 1967. *Space, Time and Architecture: The Growth of a New Tradition*, 5th Edition. Cambridge, MA: Harvard University Press.

Hughes, Thomas P. 1989. *American Genesis*. New York: Viking Books.

Koen, Billy Vaugn. 2003. *Discussion of the Method.* New York: Oxford University Press.

McCullough, David. 1977. *The Path Between the Seas: The Creation of the Panama Canal 1870-1914.* New York: Simon & Schuster.

Nye, David. 1997. *Narratives and Spaces: Technology and the Construction of American Culture.* New York: Columbia University Press.

Pool, Robert. 1997. *Beyond Engineering: How Society Shapes Technology.* New York: Oxford University Press.

"Report on the 2nd National Summit on Separate Licensing of Structural Engineers." February 15-16, 2002. Reston, VA: Structural Engineering Institute of the American Society of Civil Engineers.

Revell, Keith. 1992. "Regulating the Landscape: Real Estate Values, City Planning, and the 1916 Zoning Ordinance" in Ward & Zunz, *The Landscape of Modernity*.

Revell, Keith. 2003. *Building Gotham: Civic Culture and Public Policy in New York City, 1898-1938*, Baltimore: The Johns Hopkins University Press.

Schlesinger, Arthur Meier. 1999 (1933). *The Rise of the City: 1878-1898.*Columbus: Ohio State University Press.

Slaton, Amy. 2001. Reinforced Concrete and the Modernization of American Building, 1900-1930. Baltimore: The Johns Hopkins Press.

"SECB History" Structural Engineering Certification Board. http://www.secertboard.org/history.htm accessed March 1, 2009.

Ward, David and Zunz, Oliver. 1992. *The Landscape of Modernity: New York City, 1900-1940*, Baltimore: The Johns Hopkins University Press.

Weiss, Marc. 1992. "Density and Intervention: New York's Planning Traditions" in Ward & Zunz, *The Landscape of Modernity*.

Wermeil, Sara E. 2000. *The Fireproof Building: Technology and Public Safety in the Nineteenth-Century American City*. Baltimore: Johns Hopkins University Press.

Willis, Carol.1992. "Form Follows Finance: The Empire State Building" in Ward & Zunz, *The Landscape of Modernity*.