are not more central to the discourse of our discipline, as many mental and practical errors seem to accrue from such distinctions. As such, our disciplinary specificity will remain ambiguous until we more clearly understand the logic and illogic of our praxis; as Peters indicates, "Only then will we be able to understand how builders think in detail, how they design and construct, and what distinguishes building from other forms of human endeavor."

Philippe Block in Chapter 3 questions the received authority of certain techniques of quantification in the engineering practices of built systems. His focus is on stability rather than stress-based equations. Block's contribution helps remind us that any numerical model of the world is inherently as incomplete as it might be inaccurate. As Block notes, this requires us to question normative practices in knowledge building and perceive knowledge from an alternative perspective. Therefore, Block's text reflects the social construction of certain practices: that alternative means, techniques, and theories exist but some come to shape a particular period of practice through historically, culturally, and socially contingent factors. As in the case of masonry structures, it is not the refinement or optimization of certain techniques that yields insight into the performance and complexity of built systems, but often a fundamental shift in knowledge that yields the greatest insight.

In Chapter 4, Ivan Rupnik articulates important points regarding attempts in architecture to systematize construction through prefabrication: the systemization of systems. This examination of prefabrication approaches in the twentieth century is a disciplinary analysis of an expanded idea of what constitutes context and what architectural specificity should be in the realm of systematizing building technology. Rupnik explicates these terms with examples from Ernst May and Bogdan Budimirov.

Together the authors critique unquestioned assumptions and determinations about the role of technology and systems in architecture and engineering. Collectively, these contributions help frame a relationship between design and technology for architecture that is at once broader in its consideration of systems and yet more disciplinary-specific in its application of systems.

Chapter 1

Construction history

Between technological and cultural history

Antoine Picon

Introduction

Construction history is a thriving domain. This book provides a good opportunity to question construction history, to examine in particular the type of relation it has or should have with other domains of historical research. In this paper, I would like to examine in particular its position vis-à-vis history of technology on the one hand, and cultural history on the other.

While construction technology's relation to the history of technology may seem simple at first, a closer look reveals a series of complex problems. For construction history represents both an integral part of history of technology and a very special field with strong idiosyncrasies. What are the sources of these idiosyncrasies? Should they be cultivated or rather toned down? These are some of the issues that arise almost immediately upon the examination of the relation between construction history and history of technology.

How construction history can contribute to the historical study of culture, in the broad sense given to that latter term by anthropology and sociology, represents another interrogation. This interrogation is of course part of a more general question regarding the relation between technology and culture. On that subject, the proposition I would like to make towards the end of this article is that construction history offers today a unique opportunity to rethink the relations between technology and culture.

Construction history and history of technology

As I have just pointed out, while construction history can be considered as a branch of the history of technology, its position within this broader field appears somewhat marginal. This marginal position is especially evident in the studies devoted to nineteenth- and twentieth-century technological evolution. For these studies are dominated by the question of industrialization. In standard accounts of the

industrialization process, and despite its economic weight, the building industry is not usually scrutinized with the same attention as manufacturing. The importance given to construction is more pronounced for earlier periods like antiquity or the Middle Ages, for sure. As a whole, history of technology has nevertheless had a tendency to concentrate on other questions than those that construction history is typically interested in.

There are reasons for that situation. Some of them are the direct product of the very specific way construction history has emerged as a field. Actually, construction history was among the first domains of the history of technology to be extensively studied. The nineteenth century was marked by the publication of major contributions to the history of construction like those of Gottfried Semper, Eugène-Emmanuel Viollet-le-Duc, or Auguste Choisy.[1] Many of these founding fathers were architects or engineers. Because of that, and although construction history claimed to follow the strict rules of archeology and scientific history, the domain bore the mark of doctrinal and professional concerns. For Semper or Viollet-le-Duc, the analysis of the construction techniques of the past was inseparable from theoretical and practical questions pertaining to nineteenth-century architecture, in particular to its fundamental uncertainties regarding the question of style and how to build.[2] This attitude is especially clear in Viollet-le-Duc's *Lectures on Architecture*, in which the author tries to apply the Gothic approach to nineteenth-century architectural problems like the use of cast and wrought iron, an endeavor linked to the controversy that had risen between him and the architect Louis-Auguste Boileau a few years before the publication of his ambitious treatise[3] (Figure 1.1).

Doctrinal and professional concerns have never entirely disappeared from the field. They are, for example, discernible in studies like David Billington's *The Tower and the Bridge*, or Kenneth Frampton's *Studies in Tectonic Culture*.[4] In both cases the agenda of the author is not only historical, but also professional.

Beside architects and engineers, historians of art began to delve into construction history towards the end of the nineteenth century. Because of the origins of its main contributors, be they architects, engineers or historians of art, construction history was almost exclusively centered on physical objects, like buildings or structural types, like the Greek temple or the Gothic cathedral. This feature remains to a certain extent the case today, despite the development of studies devoted to the building professions or the production and use of materials.

In summary, in its infancy construction history was marked by doctrinal and professional questions, as well as by the importance given to physical objects. Although the field has expanded in a spectacular manner, these two features are still present today, even if in a much attenuated manner. After all, when taught, construction history is mainly present in architectural and engineering programs, or in history of art departments.

At its birth, the modern history of technology was an offspring of less professionally oriented questions like the origins of industrialization. The links that soon developed between history of technology and economic history contributed to slant the history of technology towards problems like the general mechanisms

1.1
E.-E. Viollet-le-Duc, vaulted room inspired by Gothic principles. *Entretiens sur l'architecture*, Paris, 1863–1872.

of innovation. By the same token, the history of technology rapidly abandoned the detailed study of tools and machines to give precedence to the analysis of processes, both purely technological or economical and social.

As I have already said, these differences have decreased in recent years. Compared to what it was some twenty years ago, construction history is far more autonomous from the professions of architect or engineer today. From the study of the emergence and diffusion of new materials to the analysis of the social dynamics at play in the building industry, historical processes are far more present and the precedence given to objects has greatly diminished.

For instance, this trend is easy to observe in the series of studies that have been devoted to the origin and development of concrete. Instead of focusing only on buildings and structural types, these studies have dealt with a complex mix of technological, economical and social dynamics. With the study of key entrepreneurs like Hennebique or the social structures of the early American concrete industry by scholars like Gwenaël Delhumeau or Amy Slaton,[5] we are very far from the traditional evocation of structural masterpieces created by major figures like Perret or Torroja (Figure 1.2).

This evolution is also discernible in more traditional domains like the study of Romanesque and Gothic construction. There also, the attention given to the economic and social aspects is a striking feature of many recent studies.

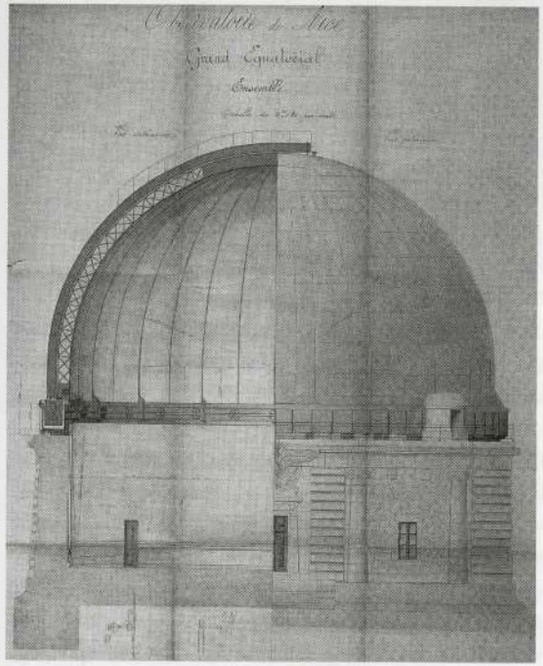
1.2
Hennebique Company Centr Office in Paris. Hennebique Archive, Paris.

1.3
G. Eiffel, Nice Observatory. Archives Nationales, Paris.

Nevertheless, construction history remains special because of its connection to problems of design, often with an aesthetic dimension. Even when it is not integrated in an architectural or engineering program, construction history, especially when studying non-vernacular realizations, is confronted by design and aesthetics. Even when it deals with builders, like John Ochsendorf's current work on Gustavino, design and aesthetics are difficult to avoid. Because of this connection the domain is marked by two seemingly contradictory features.[6]

The first one is the attention often paid to the dimensions of knowledge and theorization. Through questions like stereotomy, the science of stone cutting, or structural design, construction history has, for instance, close ties with the history of geometry and mechanics. The work of the late Eduardo Benvenuto, his *Scienza delle costruzioni* in particular, or Joël Sakarovitch's seminal study on stereotomy, *De la coupe des pierres à la géométrie descriptive*, are representative of those ties.[7] At another level, books like Bill Addis's *Structural Engineering* raise the question of a possible theorization of design.[8] In that respect, construction history is far more preoccupied with intellectual and even cognitive aspects than other domains of the history of technology.

Conversely, construction history is also somewhat special in its extreme attention to technological details. Whereas it is often difficult to get an exact idea of the machines or the processes evoked in many historical studies of industrial innovation, numerous construction history studies are based on precise and often minute descriptions. Indeed, can one understand a project like Eiffel's Nice Observatory without entering into the detail of its hydraulic mechanism (Figure 1.3)?



This tension between the speculative and the factual is of course not a monopoly of construction history. It is, however, especially pronounced in the field. It contributes to give it a special flavor that is not to be found in other fields. But at the same time it reinforces the relative isolation of construction history within the larger realm of history of technology.

Are the features I have been evoking, from the enduring presence of professional concerns to the tension between the speculative and the factual, a good or a bad thing? They certainly represent a challenge since they contribute to make the domain somewhat special. But they are at the same time full of opportunities, as I will try to show at the end of this presentation.

But before returning to this question, I would like to discuss the relations between construction history and cultural history.

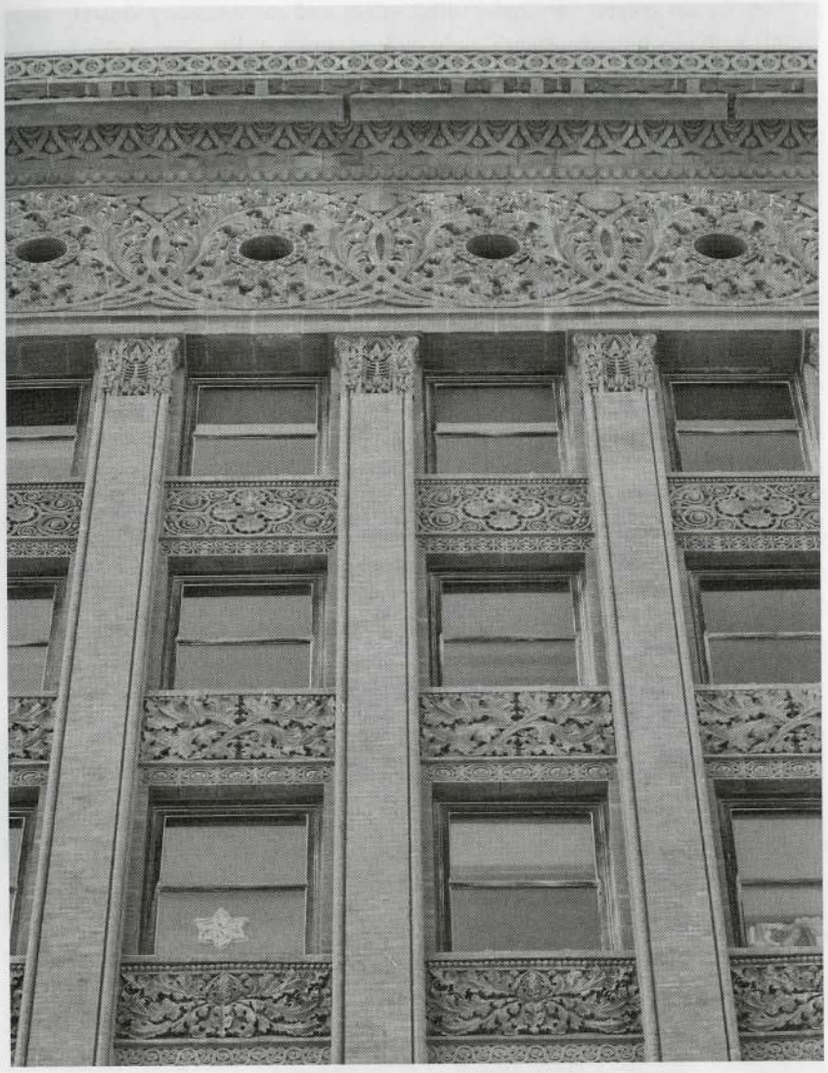
Construction history and cultural history

These relations are by no means less complex than those that exist between construction history and history of technology. What can construction history teach us regarding the culture of a given society, if one chooses to define culture as the system of shared values, representations and practices that make collective life possible?

For the nineteenth-century pioneers of the domain, these relations were self-evident. For instance, Viollet-le-Duc saw Gothic as intimately linked to medieval urban culture. In his eyes, Gothic architecture was first inseparable from civic concerns. Cathedrals were supposed to serve these civic concerns by enabling gatherings. For the author of the *Dictionnaire raisonné*, the thin ribbed vault was the direct consequence of the high cost of materials and labor that characterized urban life. Its ribbed structure implied the use of flying buttresses with the rigor of a mathematical theorem corollary. The lancet arch enabled a standardization of stone cutting, again in accordance with the cost of materials and labor. Finally, Gothic was far more than a structural principle. It was a mode of reasoning, an attitude towards life that epitomized what was truly essential and, by the same token, modern in medieval urban life. In almost Hegelian fashion, it was because of these deep roots in the culture of its time that Gothic could be considered as a universal model. Incidentally, Viollet-le-Duc did not advocate the direct transposition of Gothic forms to nineteenth-century architecture. He was never a fully fledged neo-Gothic architect. What he wanted was to capture the fundamental spirit of adaptation to the condition of the time that according to him characterized Gothic architecture; hence his attempt at transposing the Gothic lesson to modern cast iron construction in his *Lectures on Architecture*.

In Viollet-le-Duc's writings, just as in Semper's, construction problems were inseparable from ornamental ones, the latter being also in close contact with the cultural practices of their time. Hence the parallel between the Egyptian capital and Egyptian hairstyle that was self-evident for Semper.

The belief that construction represents indeed a privileged expression of culture and that it is often linked to ornamental issues was to remain present until the end of the nineteenth century. For instance, it permeated Louis Sullivan's approach



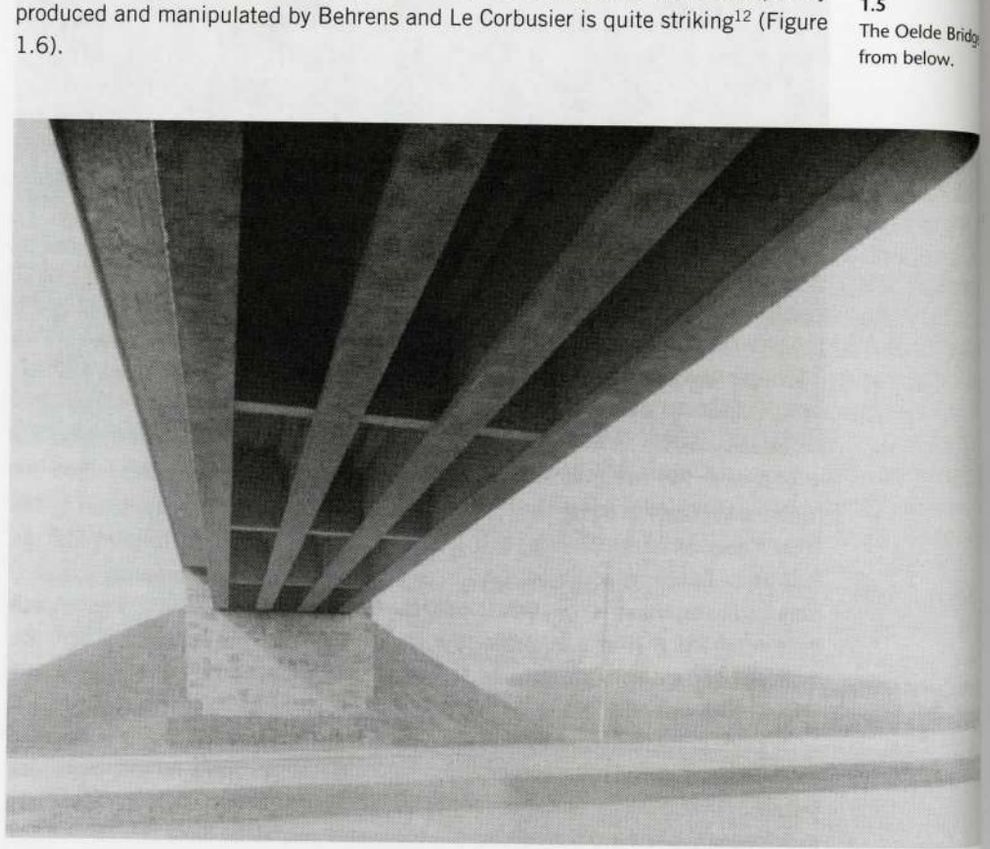
1.4
L. Sullivan, Wainwright Building in Saint Louis, detail of the decoration.

to the skyscraper problem. For him, the skyscraper was both a question of the steel frame, as exemplified by Le Baron Jenney's pioneering realizations like the Fair Store Building, and a problem of ornament.[9] Both were eminently cultural. Both had to express the dynamic spirit of the time through constructive rigor as well as through the rhythmic quality of the ornamentation. This is among others the message carried by a masterpiece like his Wainwright Building in Saint Louis (1891) (Figure 1.4).

We are still convinced by those kinds of links when dealing with traditional societies and vernacular construction techniques. We have no difficulty, for instance, in relating the structure of the South Algerian M'Zab cities to the culture of the people who have built them.[10]

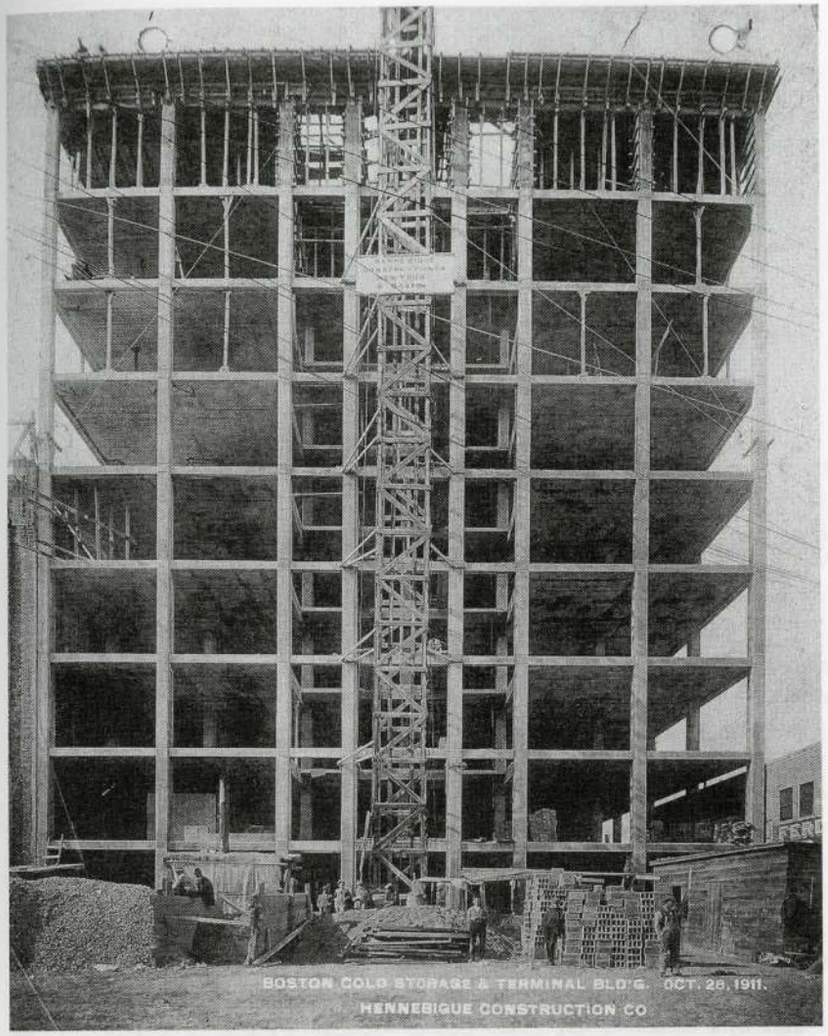
Despite our greater familiarity with modern and contemporary Western style construction techniques, their link to culture seems at first less evident. If we have no problem in relating major projects like the 1851 Crystal Palace to the emerging culture of industrialization,[11] we usually tend to be more cautious when dealing with other construction history topics, as if they belonged to a highly specialized domain that had no immediate connection with the broader issues that cultural history is usually interested in. For instance, major technological innovations like the development of pre-stressed concrete during and after World War II seem difficult to link to specific cultural issues. The historian and the critic are usually mute on such a subject when they deal with objects like the very first pre-stressed bridges, for example the bridge on the River Oelde built on the eve of World War II by the German company Wayss & Freitag (Figure 1.5).

Usually, when one tries to relate modern and contemporary construction developments to cultural issues, one has to consider their impact on architecture and engineering. To make sense of François Hennebique's realizations, historians have, for instance, stressed the connection between his use of photography and the quest for a new objectivity that characterized modern art around the same time. This quest in its turn was to mark modern architecture. The similarity between the type of photography sponsored by Hennebique and that subsequently produced and manipulated by Behrens and Le Corbusier is quite striking[12] (Figure 1.6).



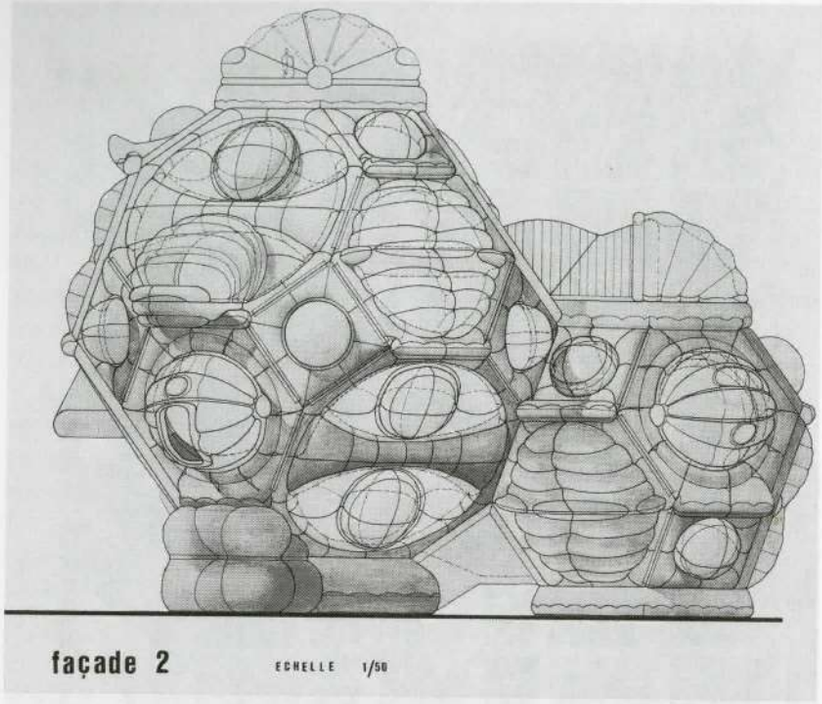
1.5
The Oelde Bridg
from below.

1.6
Shoe factory in Boston realized using Hennebique patents, 1911. Hennebique Archive, Paris.



Another set of mediations can be provided by social and economic history as well as by general history of technology. Hennebique's practice can also be interpreted in the light provided by the advent of what historian Tom Hughes has called "large technological systems" – systems raising specific problems of organization and control, systems that dwell also extensively on aggressive advertising.[13] In that respect, with his complex system of patents, franchised offices and companies, and advertising media, Hennebique is a true contemporary of someone like Edison.

In a somewhat similar way, the recent history of space and pneumatic structures reproduces a tension between militaristic and technocratic dimensions and aspirations towards a greater degree of freedom that characterize many other aspects of the 1950s and 1960s technological and social trajectory. For example, geodesic

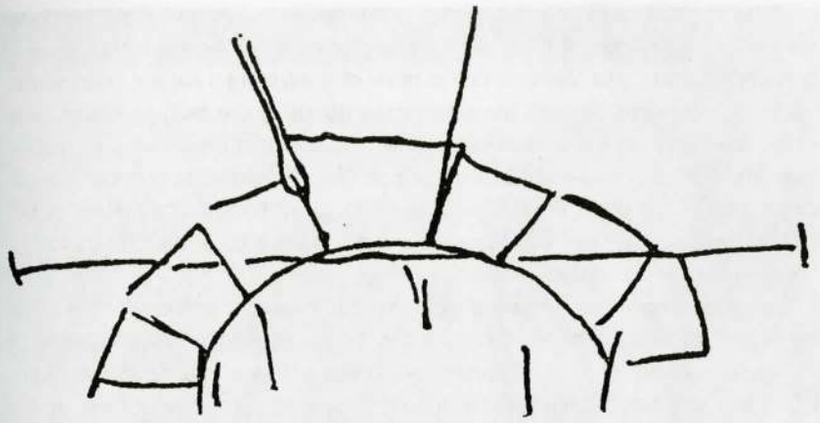


1.7
J. P. Jungmann, Dyodon, an experimental pneumatic dwelling. École Nationale Supérieure des Beaux-Arts, 1967

domes were to be found both in Buckminster Fuller's commissions for the military and in alternative communities like Drop City. Similarly, the researches on inflatable structures circulated from the military-industrial complex to 1968 counterculture[14] (Figure 1.7).

However, these links leave aside intellectual and cognitive dimensions that had been more systematically invoked by nineteenth-century authors like Viollet-le-Duc. For him, Gothic was once more synonymous with a mode of reasoning, which was in its turn plugged into the broader culture of the Middle Ages. Erwin Panovsky's famous 1951 essay *Gothic Architecture and Scholasticism* was probably one of the last expressions of this kind of approach.[15] Panovsky's main argument – the analogy between the hierarchy of Gothic architecture and the structure of scholastic reasoning – was of course disputable. Such an ambitious attempt at relating a construction mode as extensive and varied as Gothic to the intellectual world is always risky. Despite this risk and the confusion it can lead to, one cannot but be struck by the fact that construction represents an endless source of metaphors, from the vault that inspired Classical authors like Charles Perrault or Heinrich von Kleist[16] (Figure 1.8) to the cantilever exalted in various contemporary writings. These metaphors indicate that its relation to culture is far more profound than one might suppose at first.

On one side, construction points towards abstract and general thought. Even if his analysis of Gothic was flawed by excessive generalization, Panovsky was probably right in supposing that at some points in history, there are connections



1.8
Heinrich von Kleist, diagram of a vault. Letter to Wilhelmine von Zenge, 18 November 1800.

between tectonic choices and intellectual preferences. At a much more limited scale than Panovsky, I have tried in various articles to show how the theme of the primitive hut and the constructive pattern of trabeation have to do with the trend towards analytical reasoning that characterizes late eighteenth-century France.[17] The quest for structural clarity that explains the preference given to a clear-cut distinction between vertical and horizontal members – in other words, the preference given to the system of the column and entablature instead of the arch in various eighteenth-century French churches, the so-called freestanding column churches – has to do with a contemporary tendency to reason using systematic decomposition of complex objects into well-distinguished elements.

In a similar vein, contemporary structural creativity is clearly related to an evolution in the way we reason about nature. It reflected the dynamic interpretation of natural structures to be found in the scientific work of Haeckel or Darcy Thompson at the turn of the twentieth century; hence the enduring success of Thompson's book *On the Growth of Form* among architects and engineers. Later, from the 1950s on, it was to be marked by the notion of pattern that was developed in connection with cybernetics and system theory, a notion mobilized in the domain of the arts and design by a theorist like György Kepes.[18] All these connections represent a first side of what constructive metaphors are about.

But also, constructive metaphors have to do with a much more intuitive level at which our understanding of the natural constraints is dependent on our historically determined perception of the body. In order to clarify what I mean by this dependence on the perception of the body, I would like to start from a quotation from the famous Spanish engineer Eduardo Torroja.

In his 1957 book *The Reason of Structural Types*, Torroja wrote that "Vain would be the enterprise of somebody who would propose himself to design a structure without having understood to the backbone the mechanical principles of inner equilibrium."[19] Being an engineer, he saw those principles and their interiorization as something that was independent from history. I would like to challenge that position. For in the understanding of the backbone of the mechanical principles of inner equilibrium we are necessarily indebted to the way we

perceive our body and its movements. In the past decades, cultural historians have multiplied studies showing that this perception is to a certain extent a social construct. Gravity, just like a certain number of fundamental natural constraints, is always perceived through the prism constituted by our body, a historically determined body. By the same token, one can suppose that the use of constructive schemes and patterns like trabeation or cantilever is related to moments in our perception of the body. From Torroja to Frank Lloyd Wright, the history of the relation between cantilevered structures and the modern body, the heroic modern body, remains to be written.

Strangely, or perhaps not so strangely after all, the tendency towards theory that permeates construction history has not led to the full exploration of the two aspects I have just evoked. Its strong connection to design, to engineering in particular, might be partly responsible for that. Indeed, there is a marked reluctance on the part of engineers to recognize the culturally determined character of constructive choices. It is not my intention to transform all these choices into social constructs. Gravity and similar natural constraints are certainly not social in essence. All that I am arguing here is that their interpretation is always historically determined. This interpretation has among other things strong links with the historical perception of the body that is an integral part of culture.

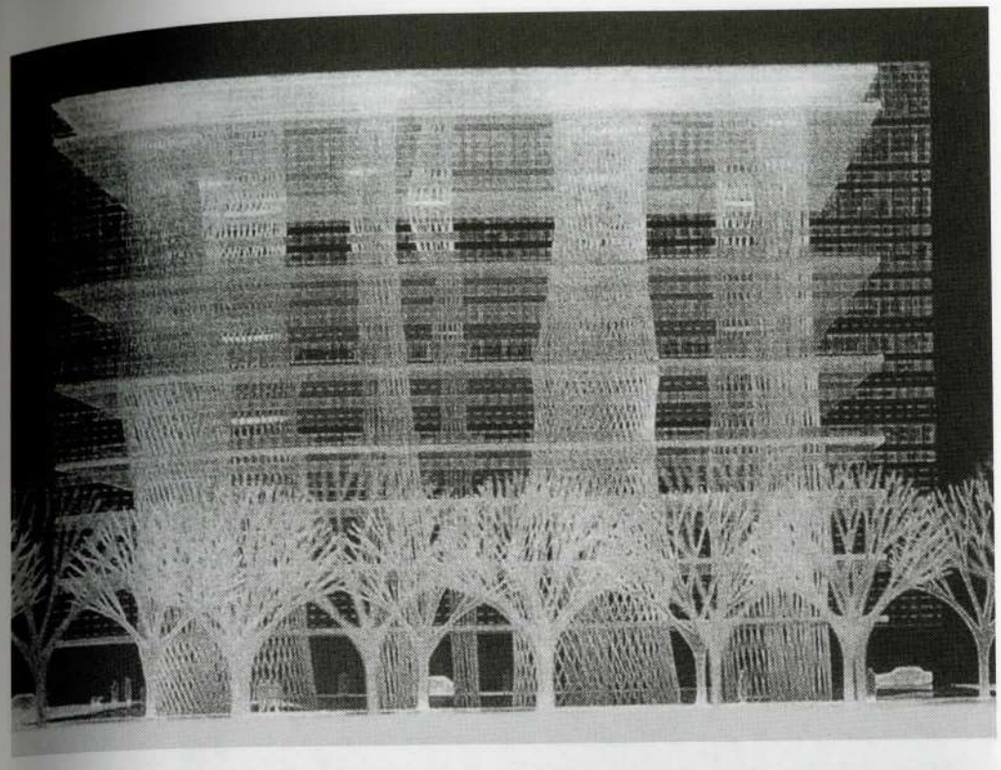
In a forthcoming book, the French architectural historian Laurent Baridon has shown convincingly how the widespread adoption of concrete relates to a preoccupation for molding the user of architecture at the turn of the twentieth century, a preoccupation shared by many architects and engineers at the time.[20]

This line of inquiry might lead us to ask what will be the constructive consequence of the digital subject and body that is emerging under our eyes. For instance, does it imply for the end of traditional tectonic evidence in favor of a systematic quest for formal complexity? In works like those of Frank Gehry, this formal complexity leads to an even more radical dissociation between form and tectonics.[21] There might be a link between this condition and the perspectives opened up by the blurring of the traditional distinction between the natural and the artificial, the organic and the prosthetic. The works of Gehry, Foreign Office Architects, and Toyo Ito are all marked by a growing gap between the architectural intention and the structural reality of the building (Figures 1.9 and 1.10). Have they to do with the cyborg condition evoked by authors like Donna Haraway?[22] Toyo Ito himself refers to the dual condition of a contemporary subject: both organic and technological, a compound of flesh, mechanical and electronic parts.[23]

There again, we have less trouble establishing this kind of parallel between traditional cultures and their specific techniques of construction. Ethnological accounts are full of analysis of vernacular indigenous construction and their relation to cosmology and body culture. We should probably be at least as ambitious when dealing with our own constructions. In that respect at least, we have to rediscover the nineteenth-century lesson, even if it was often flawed by racial and social prejudice.

1.9 (opposite top) Toyo Ito, Sendai Mediatheque, model.

1.10 (opposite bottom) Toyo Ito, Sendai Mediatheque, view of construction. The contrast between the almost immaterial model shown in Figure 1.9 and the reality of the structure is striking.



A link between technology and culture

My previous remarks were not aimed at limiting the study of the relations between construction history and cultural history to the two poles of intellectual preference, what sociologist Pierre Bourdieu called intellectual *habitus*, and down-to-earth bodily experience. I am simply advocating a broadening in order to reach these two poles instead of the self-limiting attitude that generally prevails.

Now, it seems to me that construction history is placed today in a very strategic position between history of technology and cultural history. Because of some of its idiosyncrasies, it might very well be able bring convincing answers to some very contemporary problems that history of technology has tried to address in the past decades. By doing so, it may contribute to a better articulation between history of technology and cultural history.

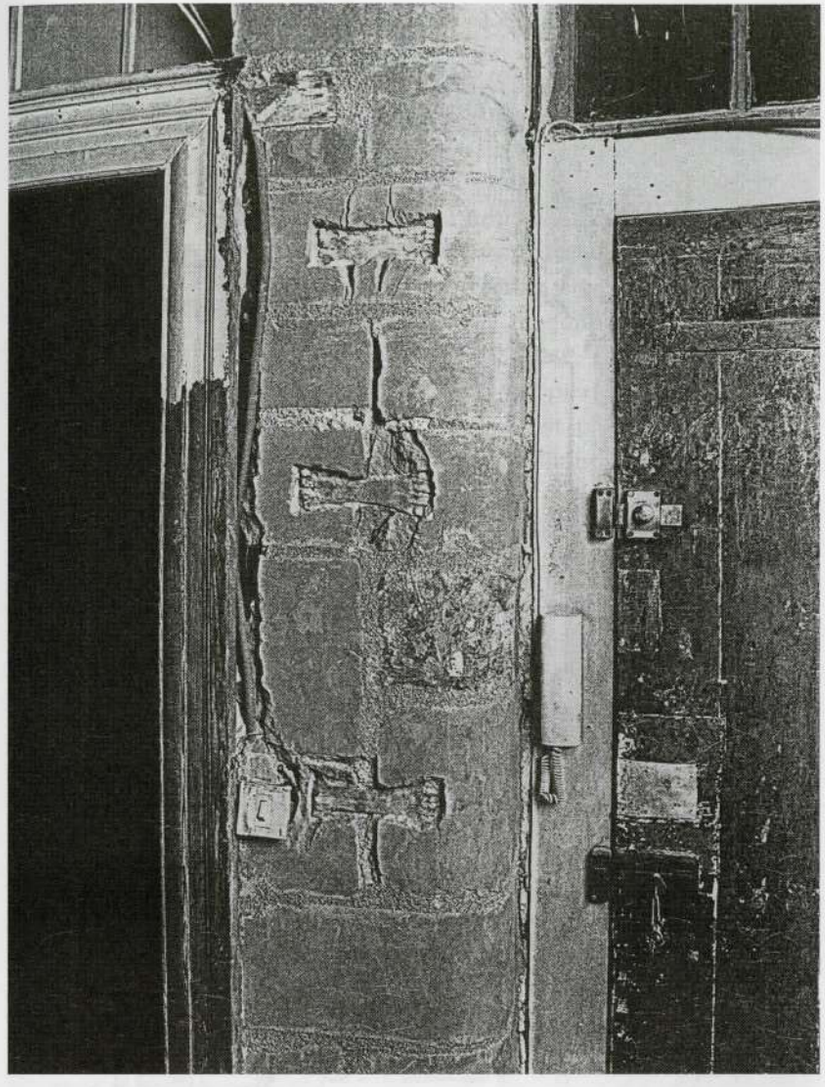
One of the key issues in recent history of technology and technology studies has been to denaturalize technology and technological progress, in other words to show how it is socially constructed.[24] In that respect, construction history might play an important role because of its seemingly natural basis. Fundamental notions of construction history like materials or structure seem indeed to have an even stronger natural basis than notions used in other domains of technological history. Perhaps the time has come to study how they are just as socially constructed as other notions.

Let us take, for instance, the notion of material. Materials seem at first defined only by nature and its laws. Even when they are artificially produced, like concrete or plastics, they certainly follow these laws. But the very notion of material is actually dependent on cultural factors. To give you an example, the implicit definition of a material that was common at the time of the First Industrial Revolution was based on the assumption that materials presented a relatively low degree of organization, when compared to more sophisticated natural or human structures. Steel was a material in that sense. The case of wood was of course more ambiguous because of its organic origin and its fibers, but a beam was clearly made of something less structural than the assemblage that constituted a roof.

Before that time, the notion was much more complex. Men lived in a world in which there was first of all no clear-cut demarcation line between the inorganic and the organic, or between a level of organization characteristic of a material and a more structural level. This explains how, for instance, bones could be considered as a material in the French city of Nantes until the second half of the eighteenth century[25] (Figures 1.11 and 1.12). Materials could often display a greater degree of organization than the structures they were part of.

Today, we are probably returning to a conception closer to the pre-industrial one with all our researches on composite and smart materials and the tendency to answer more and more questions at the level of material design rather than structural design.

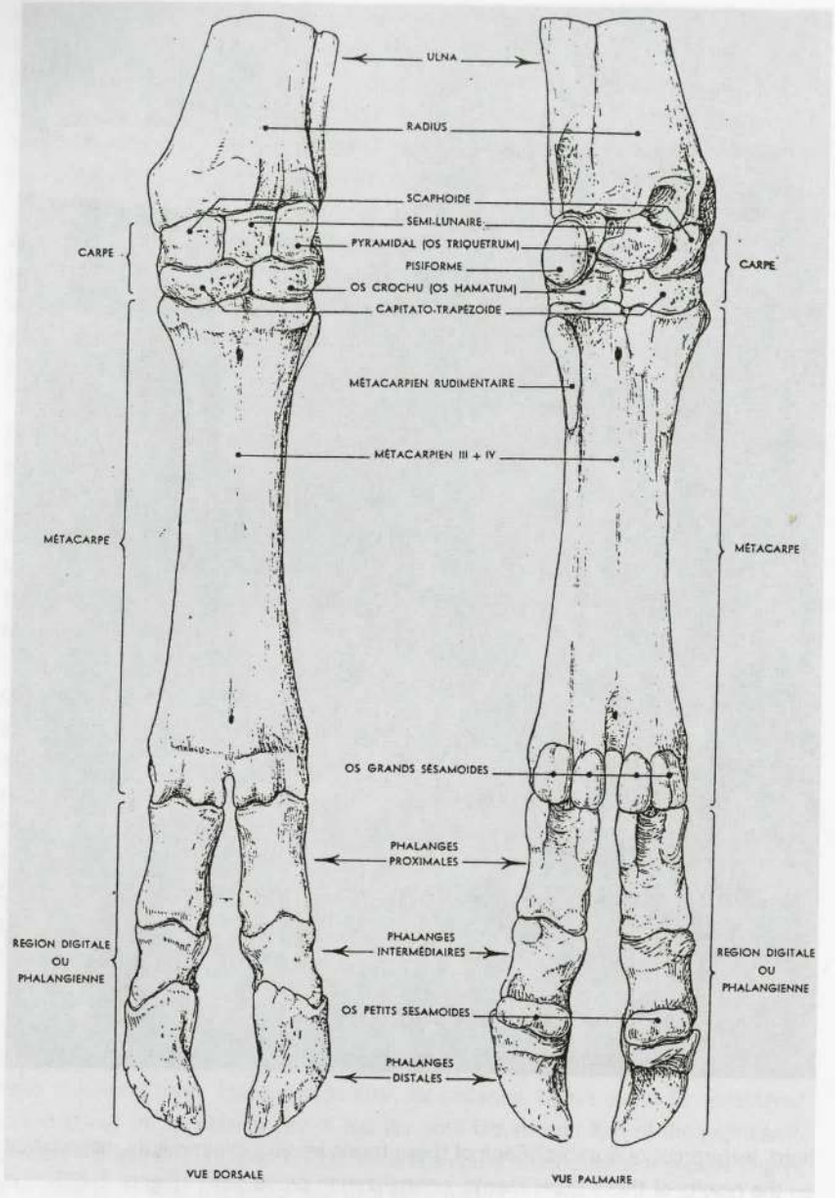
The very definition of what we consider as a material in contrast to what we see as a structure is a cultural construct. Materials are culturally and socially constructed at many other levels. Their properties, for instance, are the result of complex negotiation processes between various actors. What does it mean to be



1.11
Ox bones used as ties in eighteenth-century construction in Nantes.

hard, waterproof or durable? Each of these terms implies experiments, negotiation on the results of these experiments, normalization processes[26] (Figure 1.13). It is through that kind of process that reinforced concrete, having at first been interpreted as a series of structural systems, became gradually a material.

Similar analysis can be undertaken on the notion of structure. Far from being given by nature, this is also a cultural construct. As I have tried to show in various contributions, our present notion is strongly indebted to the eighteenth-century legacy, to the rediscovery of Gothic, and to a fluidic interpretation of the efforts developing within matter, a conception that was to lead eventually to nineteenth-century mechanics of continuous materials.[27] In that respect, it is no surprise

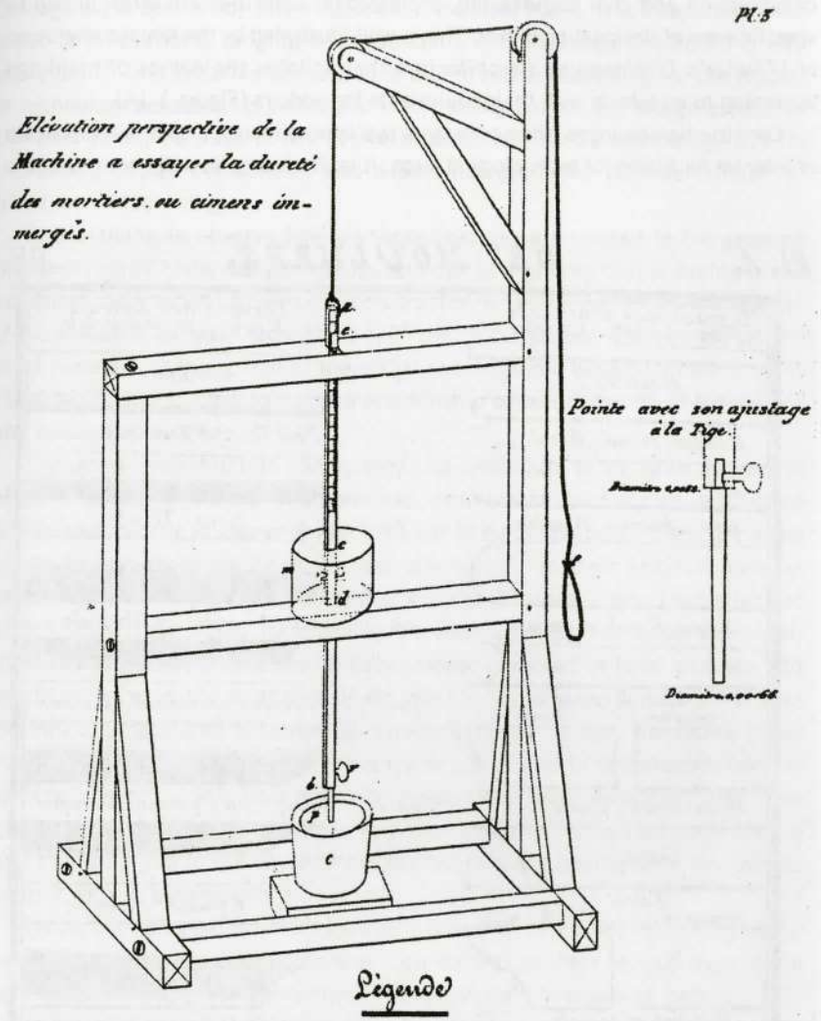


1.12
The structure of ox bones.

1.13
Joseph Louis Vicat's machine to test the hardness of concrete. *Résumé des connaissances positives actuelles sur les qualités, le choix et la convenance réciproque des matériaux propres à la fabrication des mortiers et ciments calcaires*, Paris, 1828.

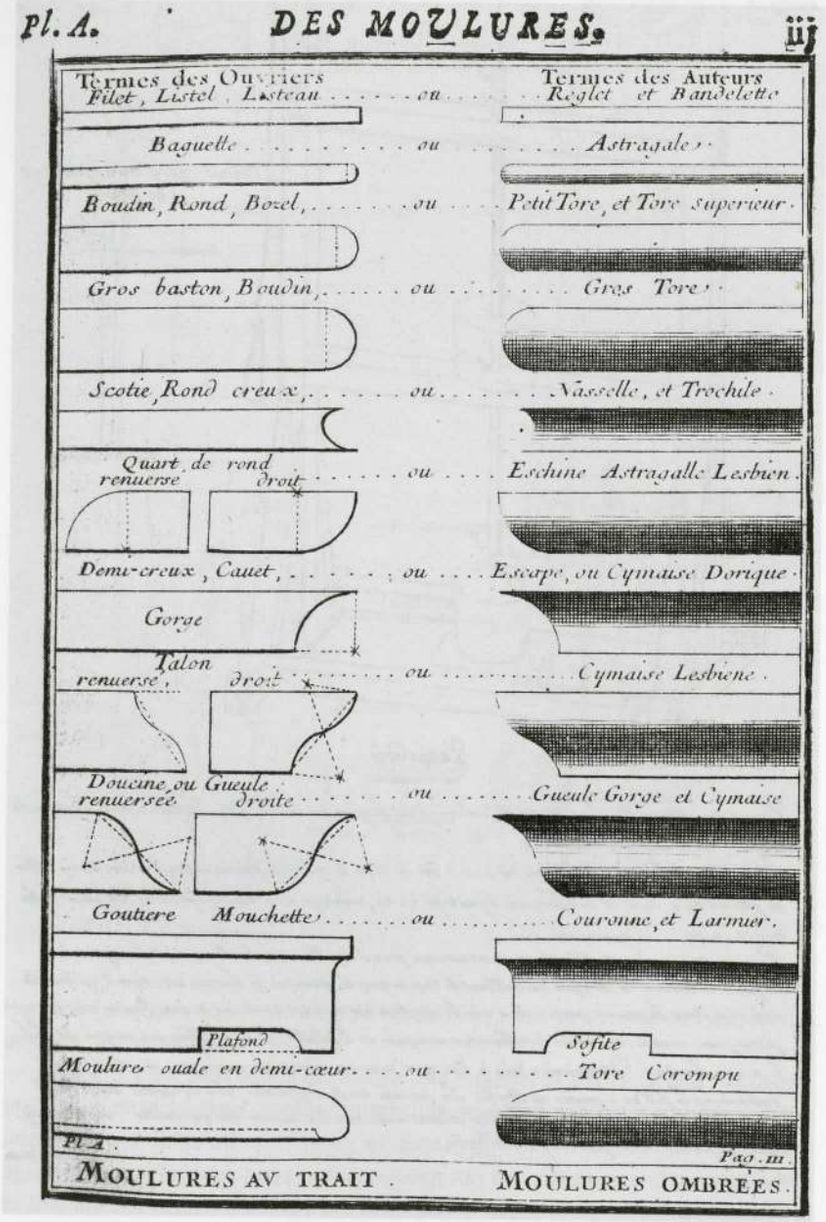
that the founder of the new discipline, Cauchy, was to be inspired by Euler's analysis of fluid dynamics.[28]

Beside the deconstruction of notions like material or structure and the denaturalization of technology, another interesting aspect of construction history is the importance of linguistic problems, of questions of pertinent vocabulary. There again, the contemporary history of technology has become more and more sensitive to this kind of issue. It has always been very present in construction history. In



construction and civil engineering, professional identities are often linked to specific ways of designating things. This is well illustrated by the famous engraving of D'Aviler's *Dictionnaire d'architecture* that collates the names of moldings according to architects with their equivalents for workers (Figure 1.14).

Construction changes often possess a systemic dimension that is there again of interest for history of technology at large. It is, for example, well known that the



1.14
C. A. D'Aviler, "De moulures," *Cours d'architecture . . . avec une ample explication par ordre alphabétique de tous les termes*, Paris: Mariette, 1720.

Chicago skyscraper is not only a question of the steel frame. It is inseparable from a set of innovations, ranging from foundations techniques to electricity and elevators.[29] This systemic dimension is all the more interesting for the history of technology because it is permeated with a strong project and design aspect. In the past years, because of the evolution of contemporary technology and its increasing design component, this aspect has gradually become crucial for historians of technology.

It is striking to observe how all these features are related to the growing interweaving of history of technology and cultural history that is taking place nowadays. The notion of the social construction of technology refers precisely to this connection between technology and culture.[30] Because it seems at first the most resistant to the notion of the social construction, construction history is capable of playing a key role in the relationship between studies of technology and cultural approaches.

Conversely, construction history may also contribute to a greater awareness of the importance of material determinations in the analysis of culture. Culture is situated; culture is always eminently local in its production – these are some of the key points made by recent cultural history. In their seminal book on seventeenth-century science, *Leviathan and the Air Pump*, Simon Schaffer and Simon Shapin have shown, for instance, how even scientific knowledge, supposedly the most universal of all cultural expressions, is rooted in local debates and practices. An essential point in their argument is how science is not a set of pure theoretical propositions detached from material reality. In fact, theoretical statements, like those regarding the existence or not of void in seventeenth-century science, are inseparable from particular questions of experimentation, and those questions are rooted in their turn in very local contexts. Nobody was ever able to build an air pump in the seventeenth century without having been in physical contact with an existing one.[31]

Being both plugged into very general cultural issues, while remaining at the same time almost always local, construction history can there again bring a useful contribution to our growing awareness of the material dimension of culture.

In a discipline or sub-discipline of history, the first phase is usually marked by the thorough investigation of the field proper, of its various possibilities and riches. Then the discovery and exploration of its frontiers becomes a necessity. Finally, these frontiers are crossed again and again, and new insights and understanding are brought from outside whereby the discipline becomes also fruitful to other fields. The history of construction has passed the first moment of emergence or the phase of consolidation. Now, the time has probably come to exchange more intensely with the exterior world, within the greater realm of history.

Notes

1 See among others the texts translated into English in G. Semper, *The Four Elements of Architecture and Other Writings*, Cambridge: Cambridge University Press, 1989; E.-E. Viollet-le-Duc, *Dictionnaire raisonné de l'architecture française du XIe au XVIe siècle*, Paris: B. Bance & A.

Morel, 1854–1868; E.-E. Viollet-le-Duc, *Entretiens sur l'architecture*, Paris: A. Morel et Cie, 1863–1872; A. Choisy, *Histoire de l'architecture*, Paris, 1899; new ed., Paris: Serg, 1976.

2 This incertitude is well conveyed by the title of the German architect Heinrich Hübsch's 1828 essay *In welchen Style sollen wir bauen?* (In What Style Should We Build?). An English translation of this essay is to be found in H. Hübsch et al., *In What Style Should We Build? The German Debate on Architectural Style*, Santa Monica, CA: Getty Center for the History of Art and the Humanities, 1992.

3 E.-E. Viollet-le-Duc, *Entretiens sur l'architecture*, "Douzième entretien." On the controversy between Viollet-le-Duc and Boileau, see B. Marrey, *La Querelle du fer: Eugène Viollet-le-Duc contre Louis Auguste Boileau*, Paris: Éditions du Linteau, 2002.

4 D. Billington, *The Tower and the Bridge: The New Art of Structural Engineering*, 1983; new ed., Princeton, NJ: Princeton University Press, 1985; K. Frampton, *Studies in Tectonic Culture: The Poetics of Construction in Nineteenth and Twentieth Century Architecture*, Cambridge, MA: MIT Press, 1995.

5 G. Delhumeau, *L'Invention du béton armé: Hennebique 1890–1914*, Paris: Norma, 1999; A. Slaton, *Reinforced Concrete and the Modernization of American Building, 1900–1930*, Baltimore: Johns Hopkins University Press, 2001.

6 J. Ochsendorf, "Los Guastavino y la bóveda tabicada en Norteamérica," *Informes de la Construcción* 57, no. 496, April 2005, pp. 57–65.

7 E. Benvenuto, *La scienza delle costruzioni e il suo sviluppo storico*, Florence: Sansoni, 1981; J. Sakarovitch, *Épures d'architecture: de la coupe des pierres à la géométrie descriptive XVI^e–XIX^e siècles*, Basel: Birkhäuser, 1998.

8 W. Addis, *Structural Engineering: The Nature of Theory and Design*, London: Ellis Horwood, 1990.

9 See, for instance, D. Van Zanten, *Sullivan's City: The Meaning of Ornament for Louis Sullivan*, New York: W. W. Norton, 2000.

10 See A. Ravéreau, *Le M'Zab: une leçon d'architecture*, Paris, 1981; new ed., Arles: Actes Sud, 2003.

11 Cf. T. F. Peters, *Building the Nineteenth Century*, Cambridge, MA: MIT Press, 1996; H. Hobhouse, *The Crystal Palace and the Great Exhibition. Art, Science and Productive Industry: A History of the Royal Commission for the Exhibition of 1851*, London: Athlone Press, 2002.

12 G. Delhumeau, J. Gubler, R. Legeault, and C. Simonnet, *Le Béton en représentation: la mémoire photographique de l'entreprise Hennebique 1890–1930*, Paris: Hazan, 1993.

13 Tom Hughes, "The evolution of large technological systems," in W.-E. Bijker, T.-P. Hughes and T. Pinch, eds., *The Social Construction of Technological Systems*, Cambridge, MA: MIT Press, 1987; new ed., Cambridge, MA: MIT Press, 1990, pp. 51–83.

14 M. Dessauce, *The Inflatable Moment: Pneumatics and Protest in '68*, New York: Princeton Architectural Press, 1999.

15 E. Panofsky, *Gothic Architecture and Scholasticism*, Latrobe, PA: Archabbey Press, 1951.

16 Ch. Perrault, *Pensées chrétiennes*, Bibliothèque Nationale de France, MS F 25575; H. von Kleist, letter to Wilhelmine von Zenge, 18 November 1800, quoted in Bernard Vaudeville, "Structure," in A. Picon, ed., *L'Art de l'ingénieur: constructeur, entrepreneur, inventeur*, Paris: Éditions du Centre Pompidou, Le Moniteur, 1997, pp. 470–471, p. 471 in particular.

17 A. Picon, "The freestanding column in eighteenth-century religious architecture," in L. Daston, ed., *Things that Talk: Object Lessons from Art and Science*, New York: Zone Books, 2004, pp. 67–99.

18 Cf. R. Martin, *The Organizational Complex: Architecture, Media and Corporate Space*, Cambridge, MA: MIT Press, 2003.

19 E. Torroja, *Les Structures architecturales. Leur conception, leur réalisation*, trans. A. Chaulet, Paris: Eyrolles, 1971, p. 28.

20 Laurent Baridon, "Le Mythe de Dinocrate. L'Architecte, le corps et l'utopie," typewritten copy of a book to be published, presented for the Habilitation à Diriger les Recherches, Paris, Université de Paris I-Sorbonne, 2005.

21 This crisis is at the core of Frampton's attempt to resurrect the modernist tectonic approach. Cf. A. Picon, "Architecture and the virtual: Towards a new materiality?" *Praxis: Journal of Writing + Building*, no. 6, 2004, pp. 114–121.

22 D. Haraway, "Manifesto for cyborgs: Science, technology, and socialist feminism in the 1980s," in *Socialist Review* 15, no. 2, 1985, pp. 65–107.

23 T. Ito, "Tarzans in the media forest," *2G* no. 2, 1997, pp. 121–144, p. 132 in particular.

24 On the social construction of technology approach, see, for instance, D. MacKenzie and J. Wajcman, eds., *The Social Shaping of Technology: How the Refrigerator Got His Hum*, Buckingham, UK: Open University Press, 1985; Bijker, Hughes and Pinch, eds., *The Social Construction of Technological Systems*.

25 G. Bienvenu, "L'Affaire de la plate-bande du grand escalier du Palais de la Chambre des Comptes de Bretagne: Expertise et pratique de chantier à Nantes au XVIII^e siècle," typewritten academic memoir for the DEA, Paris, Université de Paris I-Sorbonne, 1996.

26 On the social construction of scientific and technological properties, see D. MacKenzie, *Inventing Accuracy: A Historical Sociology of Nuclear Missile Guidance*, Cambridge, MA: MIT Press, 1990.

27 A. Picon, *Architecture and the Virtual*.

28 Cf. A. Dahan, *Mathématisations. A. L. Cauchy et l'école mathématique française*, Paris: Librairie A. Blanchard, Éditions du Choix, 1992.

29 See the classical account of C. Condit, *The Rise of the Skyscraper*, Chicago: University of Chicago Press, 1952.

30 See, for instance, MacKenzie and Wajcman, eds., *The Social Shaping of Technology*; Bijker, Hughes, and Pinch, eds., *The Social Construction of Technological Systems*.

31 S. Shapin and S. Schaffer, *Leviathan and the Air-Pump: Hobbes, Boyle, and the Experimental Life*, Princeton, NJ: Princeton University Press, 1985.