Thoughts About the Culture of the Balloon-Frame and the Steel High-Rise Skeleton

TOM F. PETERS
Lehigh University

Chicago was the trans-shipping center for most of the produce of the Mid-West in the nineteenth century, and for much of that from the West as well. Its history really began as a transportation-related event when Congress authorized the purchase of land to build a canal between Lake Michigan and the Illinois River in 1827. When the city was incorporated ten years later it had 4,179 inhabitants. It grew 400% over the next decade. This rapid pace continued, and in 1871 the city had a population of 334,270.[1] One of the commodities that flowed through Chicago was lumber. Lumberyards were as common in the city as the more celebrated stockyards, meat packing industries and grain elevators and the lumber trade was a major factor in the city's business life.[2] Until the Great Fire of 1871, most of Chicago's buildings and sidewalks were built of wood and many of its streets were paved with wooden blocks.[3] Like in every other American city, the architects and the engineers who began working in Chicago after the fire were confronted by wooden buildings at every turn. The Chicago form of light-wood framing was, however, slightly different from others. Balloon-framing had developed in the region around mid-century out of less sophisticated, East-Coast plank-framing techniques.[4] It had quickly spread outward from Chicago and eventually became the system of choice for all residential and small-scale commercial construction throughout the United States.

The crucial difference between earlier framing techniques and the one developed and used in and around Chicago, was its quasi-monolithic behavior. Its stick components were much thinner than normal in wooden construction and they were held together by nailed connections that were inferior in strength to traditional wood-connecting techniques. However, when these components and connections were used in very large numbers and spread evenly throughout a frame, the resultant high level of redundancy made a building behave as though it were structurally monolithic. Load paths could take many alternate routes through the structure. Each path would determine different stress distributions, and the loads would be "shared" between the parts with the weaker ones automatically taking less and the stronger taking more. Components could therefore be modified and even removed without risking collapse. Each configuration would determine a different load path and different stress concentrations. This characteristic of the highly redundant system was the crucial difference between the balloon-frame and earlier framing types. Architectural and cultural historians have overlooked it, but it was the one quality that permitted the development of the do-it-yourself framed and modifiable house that characterizes our American dwelling patterns and it forms the basis of our current building culture.[5] The success of suburban developments in wood like Levittown, and its longevity and adaptability depend entirely on our ability to modify large portions or replace bits of a frame amateurishly and cheaply.

This characteristic was already tentatively translated into iron construction in the early years of balloon-frame proliferation when James Bogardus extolled the virtues of his cast-iron framing and skin-construction system in the small booklet ghost-written for him in 1856.[6] In it he compares two images of the same building. The frontispiece shows Bogardus's own factory built in 1849 at the corner of Centre and Duane Streets in Manhattan, and figure 1 shows a "ghost" version of the building. The structure is fragmented and parts of it are seemingly suspended in mid-air. The point Bogardus was making in this exaggerated comparison was precisely that almost any part of the system could be removed without collapse occurring. Of course, his system couldn't have behaved so in fact, but Bogardus's pictures show us the goal and background of his construction thinking.

Like wood-framing, iron framing techniques had also come to Chicago from elsewhere. Earlier and primitive, more or less unstable frames were documented in Paris, Marseilles, London, New York, Philadelphia and St. Louis by building journals and later by Giedion, Pevsner and others.[7] There must have been more in many other cities too. Gilbert cites the export of English prefabricated housing in iron, wood and combined materials as early as 1830.[8] But it was a rigid beam-column connection that gave us the adequately stiffened frame in steel and formed the basis for high-rise construction. It developed in Chicago and New York at both termini of the former Erie Canal trade route simultaneously around 1890 and apparently nowhere else.

Conceptually both balloon-framing and steel skeletons are not monolithic and yet both behave as though they were. Does this indicate something special in the way engineers and contractors thought in those two cities at that time? What does this tell us for architectural design in our culture?

If we regard framing solely for its monolithic or non-monolithic structural behavior, the question immediately arises whether there can be a direct connection between the similar types in the two materials? Bogardus's illustrations seem to indicate that there may be. No one has yet turned up any positive proof, any textual documentation of the influence of the wood frame on the iron frame, but that does not mean that there was none. The clue to an answer will lie in the thought patterns of contemporary Chicago and New York engineers. We have to try and find out how the technologists, the engineers and the builders of the time thought. It's not easy. There is a single note in Engineering News in 1903 that suggests a conceptual relationship between light-wood and steel framing.[9] But other than that, no written link has yet come to light.

Architectural history has fed on myths relating iron framing to birdcage construction and to bamboo scaffolding in the Philippines that were both cryptically attributed to William Lebaron Jenney, but how much closer to home and more natural to a practical builder the balloon-frame would be.[10] This is all the more true since the issue of scale, which is all-important to the behavior of construction and is the bread-and-butter of structural engineering, is hardly addressed by these mythical examples. Function is independent of scale, and there are many examples of engineers influenced by the functioning of a biological or mechanical organism at another scale, like Marc Brunel in the development of the Thames Tunnel shield in 1824, but I know of no examples of engineers being influenced in structural design by organisms at other scales. Structure is not independent of scale. In view of the prior history of greenhouse construction, Paxton's incomprehensible image of the Victoria Regia lily as the inspiration for the Crystal Palace structure must be considered an illustration after the fact rather than a model. It is only people who are unfamiliar with structural principles and the "model laws" of engineering like John Ruskin or D'Arcy Thompson who could blithely relate small organisms directly to large-scale structures.[11] Builders, and especially engineers do not do this, they work with structural rather than with formal analogies: the issues are conceptual rather than visual. It is therefore unlikely that Jenney would have chosen a birdcage or unstiffened scaffolding as his model.

Carl Condit makes a much more appropriate observation when he writes that Ithiel Town's lattice bridge patent of 1820 corresponded in concept to the later balloon-frame.[12] Town was an architect known for his development of the "Federal Style" in architecture, as well as a bridge builder. The Town lattice girder in wood depends on multiple and repetitive connections and components like the balloon-frame. It also shares the same ability to accommodate physically to external forces by absorbing energy in its multiple, semi-rigid connections, and it also behaves monolithically because of its redundancy in the same way the balloon-frame does. European engineers imported the lattice truss and built it in both wood and iron. Gregory Dreicer is currently writing a book that will make the connection between Town's lattice and European iron truss development clear.[13] So, once again, in another construction area, we have the strong indication of a conceptual connection between a specific form of wood construction and iron framing techniques.

Town's papers have all but disappeared, so it is fruitless to speculate on the relationship between his bridge and the balloon frame. We cannot know unless someone discovers new material, whether Town knew the lumberyard owner Augustine Taylor or the contractor George Snow who were the reputed inventors of balloon-framing and who both came to Chicago from the East Coast. We also do not yet know just how the balloon-frame really did develop in the Chicago area and who else may have been involved. But what the conceptual similarities between the bridge and the house frame do indicate is the probability of a common background of thinking about structural behavior, the understanding that the whole is more than merely the sum of the parts.

One interesting fact about the balloon-frame and steel high-rise frames, is that they are in principle both open systems. Many earlier wooden and iron frames were closed systems, that is ones in which the structure and the form are identical. They were specific to one building and had to be substantially modified in order to make another. We can see the difference between the two types if we compare two contemporaneous British buildings, the Palm House at Kew Gardens of 1848 and the Crystal Palace of 1850. The first is a closed system. The stiffening of the structure is guaranteed by the semi-circular ribs of the nave and the two domical apses at either end. It is due to the form and not inherent in the structural module itself. This type of structure requires only one level of design: the structural and the formal design are a single process. The structural module of the Crystal Palace on the other hand, is a complete object with its own stiffening system, but with no preconception of what the final form of the building will be. This type of open system needs two levels of design: the design of the module and then the design of the form. The open system of frame construction that characterizes both balloon- and steel-framing corresponds to a particular way of thinking about building that is specific to our culture and may have originated in Chicago. It may prove to be one element of a "Chicago School of Technological Thought" rather than a Chicago School of Architecture.

In 1893, in what was perhaps the first book on high-rise construction in iron and steel, William Birkmire attributed the use of steel in construction to the need to reduce the thickness of building walls at the ground floor where prime rentable space lay. [14] Since he was concentrating on the construction of what were then the world's tallest buildings, there was no reason for him to trace the construction form back to its primitive antecedents. No one who followed him, like Joseph Freitag, did either. However, there is nothing strange in a close connection between wood and iron construction. The first large-scale iron structure in the Western world, the Ironbridge of 1779, used details that were typical of traditional wooden construction. Only gradually, in bridges like Thomas Telford's Coalport Bridge of 1816 or his Tewkesbury Bridge of 1826, do the lap-joints, dove-tails, mortise-and-tenon connections, pegs and wedges give way to what we now consider typical iron connection techniques with lugs, flanges and bolts. It took time to translate connecting technology from one material into another.

An interesting fact about balloon-framing, like Town's wooden bridge patent and the work of his followers, is that at least two of their most prominent forms of connecting technology were influenced by iron construction. The first are non-axial connections like face-nailing, and treenails in the case of the bridges. These are analogous to bolting or riveting in iron construction and almost totally absent in pre-iron construction where all main connections were traditionally axial. The second form is the use of iron connectors, such as strap-hangers or cast-iron shoes to connect axially organized members through the mediation of bolting which is a face connection. Here the proximity of wood to iron construction is even closer. This form may have developed simultaneously in both materials, with the iron connectors of wooden bridges becoming the gusset and splice plates of steel high-rises. This is where archaeology could provide help. We need to document transitional forms both in iron and wooden construction that may provide us with clear information to substantiate this hypothesis or develop another.

Can we see such transitional forms, for instance in Jenney's Home Insurance Building of 1886 or in his Manhattan, Isabella and Venetian Buildings (1890-1892). They seem to form the transition between the earliest structures and the fully developed frames by Corydon Purdy for Holabird and Roche like the Monadnock II (1893) or the Old Colony (1894)?[15] More research is definitely needed to clarify these questions.

NOTES

1 for the development of Chicago until the year of the fire, see: Sheahan & Upton: *The Great Conflagration. 1871* Chicago: Union Publ. Co., pp. 19-28

2 ibid., p. 45

3 ibid., pp. 39, 40, 45, 51, 55, 56, etc.

4 Gregory Clancey is currently researching this development at MIT

5 The characteristic was discussed in Peters: An American Culture of Construction, *Perspecta* 25. 1989 Rizzoli. It was not noted by Sigfried Giedion: Space, *Time and Architecture.* 1941 Harvard University, pp. 274-276, or by Carl Condit: *American Building Art*, 19th. Century. 1960 New York: Oxford University, pp. 22-24, 279-280; *American Building.* 1968: Univ. of Chicago Press, pp. 43-45, 58

6 James Bogardus: *Cast Iron Buildings: Their Construction and Advantages.* By J.B., C.E. architect in iron, iron building, corner of Centre and Duane Sts. 1856 New York: J. W. Harrison, printer. Although the title mentions Bogardus as the author, Bogardus himself, in his preface "to the reader", states that his friend, John W. Thomson, A.M., wrote it.

7 Giedion, Pevsner

8 Gilbert Herbert: *Pioneers of Prefabrication. The British Contribution in the Nineteenth-Century* 1978 Baltimore/London: Johns Hopkins

9 *EN* vol. 50, #9, letter to the editor, Aug. 27, 1903 "Balloon construction for steel skeleton structures" by Louis L. Calvert. (Thanks to Elwin Robison, Kent State for the reference)

10 Freitag did call monolithic, three-dimensional steel framing "cage construction," but there does not seem to be a link here. (Joseph Kendall Freitag: *Architectural Engineering.* 1895 New York: Wiley)

11 Ruskin: *Stones of Venice.* 1951-53 London, especially vol. 1, and D'Arcy W. Thompson: *On Growth and Form.* For Brunel, see: T. F. Peters: *Building the nineteenth century.* forthcoming in MIT Press

12 *American Building.* 1968: Univ. of Chicago Press, p. 58

13 Gregory Dreicer, a historian of building technology is currently writing a book on the subject.

14 William Birkmire: *Skeleton Construction in Buildings.* 1893 New York: John Wiley

15 Purdy himself credited British engineers with the origin of the idea for tall building construction in steel. It is not sure, however, whether this was not a politeness of Purdy's toward his British interviewer. (B. H. Thwaite: The Use of Steel in American Lofty Building Construction, in: *The Journal of the Iron and Steel Institute*, vol. 65, 1904 London: Spon, p. 392)