CHAPTER 5

JOHN ROEBLING AND THE SUSPENSION BRIDGE

The first American structural artist to attract international attention, and the only nineteenth-century structural engineer after Telford to rival Eiffel, was John Augustus Roebling (1806–1869). Although a generation older than Eiffel, Roebling’s career did not properly end until his son managed to complete Brooklyn Bridge just six years before Eiffel finished his tower. Roebling and Eiffel took iron in opposite directions; the former hung structures in flexible suspension, the latter framed them in rigid arches. Both initially gained international fame by creating in wilderness settings new forms for railway bridges and both ended their structural careers with unique designs in their countries’ most important cities. Yet Roebling and his ideas belong to his time—that of Stephenson and Brunel—because, to a far greater extent than Eiffel, he had to struggle with form and to do it largely empirically on the basis of field experience. In this regard, he may be compared with his best-known contemporary engineer, Brunel.

Brunel and Roebling

Both Brunel and Roebling were born in 1806, and both were trained abroad: Brunel in France, Roebling in his native Germany. Both married in 1836, and by 1841 both had established major new enterprises: Brunel, the Great Western Railway, and Roebling, a wire rope manufacturing plant. Both completed world famous railway bridges in the 1850s, and the greatest spanning bridge design of each was built posthumously. Both men proposed grand schemes for immense works, based on elegant, detailed, and carefully thought out plans. None of their structures failed and the greatest of these still serve their intended purposes.

But similar as the two men were, their differences are of even greater significance. Brunel, rising rapidly to prominence, was a national figure by 1841, at which time Roebling was still an unknown employee with not a single design realized. Brunel designed a staggering variety of structures while promoting vast projects in rail lines, giant ships, and terminals; Roebling, by contrast, had as early as 1826 set his design imagination on one type of structure only, and everything he subsequently did was directed toward that single-minded goal. In personality, Brunel was outwardly ebullient but inwardly pessimistic; Roebling appeared always to be the stolid, gloowering German, whereas inwardly he seethed with an almost inchoate romantic idealism. Brunel followed a famous engineering father; Roebling fathered a remarkable engineering son. Brunel’s structures, for all their imaginative flair, characterize the end of an era both in the choice of form and in the dominance of Great Britain. Roebling’s works, on the other hand, signaled the beginning of a clear understanding of suspension bridge behavior and the advent of the United States as a technological and political power.
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But of all the contrasts, the most central lies in their ideas on structural design as an art form. Roebling consciously wrote about his structures from an aesthetic point of view, as did Telford and Eiffel. Possibly Brunel, had he lived as long as Roebling, might also have reflected on appearance and symbolism, but his style as seen in the works themselves was not as developed as Roebling's, and would have given him less to draw upon for such ideas. By the end of Brunel's life, the great ships overwhelmed his imagination, leaving Saltash in their wake. In the last years of his life, Roebling had his wire rope factory so well organized that he could spend his time at bridge sites concentrating on design and construction. Brunel's nonstructural businesses submerged his talent for structural design, whereas Roebling's powerful design motive disciplined his business ventures.

The Immigrant Engineer

Roebling was born in Mühlhausen, midway between Göttingen and Erfurt, in the year Napoleon defeated the Prussians at nearby Jena. He grew up in a middle-class family, and showed, early, a talent for mathematics, as well as a restless independence. His studies concluded in 1826, when he received an engineer's diploma from the Royal Polytechnical Institute in Berlin, founded only sixteen years earlier. Roebling was as well educated in engineering as anyone of his generation, and had far more formal training than nearly all of his British or American contemporaries.

After a few years in the Westphalian road service, he became convinced that his future lay elsewhere. On May 11, 1831, following the unsuccessful 1830 revolution in Europe and subsequent repressions, Roebling with his brother and a small band of German emigrants left Mühlhausen and headed for America. They arrived in Philadelphia on August 6 and after several months founded a German farming community near Pittsburgh, calling it Saxonburg. John Roebling was the leader, but for him farming was only a means to the end of practicing his profession of bridge design.

John Roebling and the Suspension Bridge

In 1837, Roebling became an American citizen. Bored with farming, he took a job as an engineer for the state of Pennsylvania, building dams and locks, and surveying line for a prospective railroad route. He soon became principal assistant to the chief engineer of the state. At Johnstown, Pennsylvania, Roebling became familiar with the newly constructed Portage Railroad, where long canal boats were hauled up mountains by hemp ropes. He successfully replaced hemp with iron wire rope and, in the summer of 1841, he established a factory for wire rope at Saxonburg.

Having won an 1844 competition, Roebling built his first suspension bridge, which carried a canal over the Allegheny River. By 1849, when he moved his factory to Trenton, New Jersey, he was a success at both factory production and bridge building. Roebling's first suspension bridge for a roadway was built in Pittsburgh, over the Monongahela River in 1845. His next major works were the 821-foot-span Niagara Falls rail and road suspension bridge completed in 1855, and the Cincinnati suspension bridge, begun in 1856, which was interrupted by the Civil War and eventually completed in 1866.

In March of 1857, Roebling wrote a letter to Horace Greeley, published in the Tribune, announcing his intention to build a bridge over the East River. Greeley himself had proposed a bridge in the Tribune as early as 1849. In April of 1867, a charter was finally granted by the New York legislature, and in September of that year Roebling presented his plans in Brooklyn. The statement with which his written proposal began is perhaps his most noted; it claims, among other things, that "the great towers ... will be ranked as national monuments. As a great work of art, and a successful specimen of advanced bridge engineering, this structure will forever testify to the energy, enterprise, and wealth of that community which shall secure its erection."1

In February of 1869, Roebling presented his plans to a consulting board that included the president of the newly reconstituted American Society of Civil Engineers, William Jarvis McAlpine, and Henry Lathrop, son and namesake of the architect chosen by Thomas Jefferson to rebuild Washington, D.C., after its burning by the British in 1812. On June 28, 1869, Roebling's foot was crushed by a ferry boat while he was surveying for the bridge, and he died of lockjaw on July 22. His eldest son, Washington A. Roebling, became chief engineer for the bridge at age thirty-two.
Roebling at the Limit of Structure

Roebling’s last three major designs—those at Niagara, Cincinnati, and Brooklyn—were each as close to the limit of scale as any other work in the nineteenth century. In other words, like Telford’s Menai Bridge, they were about as light as possible, yet safe and enduring. We shall begin by considering the first of those three designs—and the only one not still standing—the Niagara River Railway suspension bridge (figure 5.1).

In his report on the bridge, which was published in Great Britain, Roebling noted that the total cost was under £80,000 and made the startling claim that “the same object accomplished in Europe would have cost one million pounds, without serving a better purpose or insuring greater safety.” This stupendous difference, a factor of over ten, is not without justification when the cost of this bridge is compared to the Britannia Bridge completed just six years earlier.³

Roebling further stated that the total weight of the bridge was less than 1,000 tons.⁴ If all this is taken to be the weight between towers (a high estimate), then the weight per foot would be 2,430 pounds compared to 7,000 pounds at Britannia, even for its much shorter spans. Thus, Roebling’s design is considerably cheaper and lighter than Britannia. Yet, Roebling claimed that his structure did not sink under loads any more than did the tubular bridge form; specifically he stated that his bridge was as stiff as Stephenson’s Conway Bridge.⁵

The price Roebling paid for this lightness and economy lay in the necessity to use wood in the deck and in the restriction of locomotive speed to 3 miles per hour. Still, the Niagara Bridge confounded nearly all engineering judgment of the age, which held that suspension bridges could never sustain railway traffic. For 42 years the bridge served well, although it needed much maintenance. A few more thousand dollars put into the initial work would have saved much of that maintenance cost later on.⁶ The bridge was removed when railroad loadings so increased as to make it no longer economical to maintain.

The Niagara Bridge was a technical tour de force never again to be repeated. It showed Roebling’s talent for successfully completing a work of huge proportions with a minimum of resources. As he put it himself, he was “in a country where the engineer’s task is to make the most out of the least.”⁷ But although the Niagara Bridge was a technical triumph, it was not an aesthetic masterpiece. It was, however, an essential proving ground for Roebling’s last two major works because it showed him just how far he dared go. When the bridge was nearing completion, he got word that the Wheeling bridge of his principal rival, Charles Ellet (1810–1862), had blown down in a wind storm. Failure of this 1,010-foot span, then the longest in the world, dramatized the fact that, as Roebling put it, “a number of such fairy creations are still hovering about the country, only waiting for a rough blow to be demolished.”⁸

However, Roebling himself was not so sure how light he could make the Niagara Bridge without exceeding its limits; upon hearing of the Wheeling failure, he immediately wrote his chief engineer in Trenton, “I shall want for this bridge at least another coil of rope . . . as soon as you possibly can do it, send it by Rail Road. . . . I am
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anxious however to secure the new floor well by stays.” The italics are Roebling’s. He was, as usual, at the construction site to follow the entire field operation.

The profile of the bridge shows all sorts of stays tied between the bridge deck and the floor of the valley. This strange array of cables gives the bridge an uncertain look. It visually expresses the empirical nature of the structure, having a kind of reverse support. Roebling had reached the limit and now he could safely, in his own mind, go to longer spans, in somewhat less harsh environments, and dedicated to the supreme goal of structural engineers—to unite beauty and utility in urban public works.

The Ohio River Bridge

In 1846 Roebling had proposed a bridge over the Ohio River at Cincinnati with two 788-foot suspension spans connected at mid-river by a gigantic stone pier 200 feet high. Ten years later, and after the successful completion of the Niagara Bridge, Roebling began construction of a revised Cincinnati design crossing the river in one 1,057-foot suspension span, the longest in the world (figure 5.2). The two other bridges over 1,000 feet in span (neither of Roebling’s design)—the one at Wheeling and the 1851 Niagara River carriageway suspension bridge—were both destroyed in wind storms.

It was in his final report to the bridge directors in 1867 that Roebling for the first time in a more coherent way let his ideals on aesthetics and symbolism flow into his technical writing. His Niagara Bridge had stood up against all predictions of failure, his Ohio River design was now completed, and his greatest design had suddenly become politically possible thanks to the terrible ice blockages during the winter of 1866–67 in the East River between Manhattan and Brooklyn. Roebling was now internationally recognized as America’s foremost bridge designer. The Cincinnati Bridge report would be, as it sadly turned out, his valedictory on structural art.

Roebling’s Ideals

Woven into the Cincinnati report are Roebling’s ideals for structural design, and supporting those a set of ideals for mid-nineteenth-century American society. In his general remarks, Roebling announced “that invention which attains to the highest perfection in its skilful production and application to the various arts of life, will rank also highest in the scale of social advancement and political power.” He proclaimed tech-
nology as the basis for social welfare and not merely for material welfare
for, as he continued, “the material forms the basis of the mental and
the spiritual; without it the mind may conceive, but cannot execute.”

However naive Roebling’s connection between material and spiritual
may sound, it is the fundamental premise for his work and cannot
be dismissed, the more so because the material basis becomes spiritual
through an ethic central to structural art. Roebling immediately de-
defined this ethic with the statement that “where strength is to be com-
bined with lightness and elegance, nature never wastes heavy cumbersome
masses.” It is an ethic of using the least resources and it is expressed
for Roebling, by “the architects of the Middle Ages [who] fully illus-
trated this fact by their beautiful buttresses and flying arches, combina-
tions of great strength and stability, executed with the least amount
of material.” It is the visual expression of lightness and strength which
can lead to works of art, but there must also be an integration of form.
In suspension bridges with a thin, spanning deck structure, Roebling
argued, “the elevation of the bridge floor would be too light in appear-
ance, as compared to the massiveness of the towers.” But when dia-
gonal stays and floor trusses are added, then “the whole has a pleasing
effect, and at the same time presents strong and reassuring proportions,
which inspire confidence.”

In other words, lightness alone is not suf-
ficient for appearance; the two major parts, tower and deck, must be
related to one another by stays to give an overall impression of both
unity and confidence. Had this judgment been seriously contemplated
sixty years later, engineers could have avoided a whole series of faulty
suspension bridge designs culminating in the incredible thinness of the
deck in the first Tacoma Narrows Suspension Bridge, which collapsed
in 1940.

Roebling proceeded to discuss the imposing stone towers, which
he noted should not be highly ornamental but rather “of simplicities,
massiveness, and strength.” He then announced a major ideal. “Public
works should educate public taste. . . . In the erection of public edifices,
therefore, some expense may and ought to be incurred in order to sat-
sify the artistic aspirations of a young and growing community.” This
may seem, in our age, to be a call for expensive ornament, but Roebling
was referring to expense in design thinking rather than in construction
materials. He made this clear in describing his tower design: “the mas-
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ving a buttress. This feature of buttresses is preserved throughout
the whole height, not only on account of appearance, but also for the
ake of strength, to save material, and to reduce the weight upon the
foundation.” His design attains its visual power by combining use (re-
duced materials) and beauty (buttress form), and as such follows the
lead, as Roebling himself emphasized, of “medieval architecture
[which] is distinguished for its remarkable lightness and great strength
at the same time, owing to the judicious use of the buttress.”

How utterly different is this reaction to the Gothic from the pious
facade-making that dominated so much of the so-called Gothic revival
of the same period. Much of the Gothic revival merely consisted of
building lovely reminders of an imagined past as a protest against the
industrial world. Roebling, by contrast, was able to imagine how new
spiritual ideals might arise from the industrial world. For him, the
Gothic was not a form to copy, but a design ideal to study. He saw
in the Gothic the ethic of conservation which underlay the aesthetic
of structural art.

Once again, this time in describing the two cables themselves,
Roebling observed that wrapping the seven strands (each with 740
wires) into each of the cables “gives them the appearance of solid cylin-
ders; it has a pleasing effect, and its solid aspect inspires confidence.”

Finally, in summarizing his completed work, Roebling announced
again a general ideal for design: “the present age is emphatically an
age of usefulness. The useful goes before the ornamental. At the time
when Grecian culture was shaping the human mind, the reverse was
the accepted rule; first the ornamental, then the useful.” He concluded
from this contrast that “the general interests of mankind are more pro-
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moted by the present than it was by the ancient maxim.” Here is
the midcentury contrast between the structural ideal and the architec-
tural fashion. While Roebling was studying the making of iron wire
and the effects of wind on suspension structures, his architectural col-
leagues were traveling to Greece to copy down the old forms for use
in new facades.

Much of the protest against technology then and now sees in it
only a crass materialism. This is why Roebling took the time to defend
his age and to proclaim the virtues of industry. “No matter what may
be charged against the material tendencies of the present age, it is
through material advancements alone that a higher culture of the
masses can be attained." For Roebling, the construction of expensive opera houses, palaces, banks, and so on, will never bring the "higher culture of the masses" that the building of the railroad will. The one merely uses up materials to express wealth, whereas the other allows "the works of industry [to] be soon broadcast over the surface of the earth, [so that] want will disappear."20

Of course, as words alone these are indistinguishable from the loud praises so often sung in Roebling's time for the glories of technology. They only stand out because of Roebling's works. When words and works go together, each is enriched by the other. Roebling was building not just for a profit; indeed it is unlikely that he made much money from his bridges. Nor was he writing just for publicity. He did both building and writing to express his ideals for society: that the spirit can be uplifted by understanding technology and by creating out of it superior works that people can afford, that they can openly use, and that they can aesthetically enjoy. That is the meaning of technology, and that is the want to be satisfied: not just material needs but "a higher spiritual culture."21

This view allowed Roebling to appreciate both the French Gothic and British industrialized iron. With respect to the latter, he stated that "Telford's successful accomplishment of the old Menai suspension bridge . . . was the great feat of those days" and that it was "to the genius of the late Robert Stephenson [that] we owe the tubular bridge, while it was reserved for the ingenuity of Brunel, Jun. to illustrate an apparent perfection by the construction of the Saltash Bridge." However, he continues, "these have now ceased to serve us as models."22 Roebling's reaction to the great works of the recent past is that found in all artists of the front rank. These artists are stimulated by, and learn from, their antecedents, but in their mature works they are on their own. At the time of his Cincinnati report, Roebling had reached his full stature. Four months later he submitted his plans for the proposed East River Bridge, and with that design his career ended. Yet, when completed in 1883, the Brooklyn Bridge (figure 5.3) would open up a new period in structural engineering, and it would symbolize, along with Eiffel's tower, a new period in history—a period in which the technological world was to become the central dominating aspect of human life.