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ART AND IRON AND STEEL

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Works of engineering and technology are sometimes viewed as the antithesis of art and humanity. Think of the connotations of assembly lines, robots and computers. Any positive values there may be in these creations of the mind and human industry can be overwhelmed by the associated negative images of repetitive, stressful and threatened jobs. Such images fuel the arguments of critics of technology even as they may drive powerful cars and use the Internet to protest what they see as the artless and dehumanizing aspects of living in an industrialized and digitized society. At the same time, landmark megastructures such as the Brooklyn and Golden Gate bridges are almost universally hailed as majestic human achievements as well as great engineering monuments that have come to embody the spirit of their respective cities. The relationship between art and engineering has seldom been easy or consistent.

Arguably, the assembly-line process associated with Henry Ford made workers tools of the system, but Ford also wanted to make automobiles affordable to working people, and he paid his own workers sufficiently well that they could save to buy the cars they made. The human worker may have appeared to be but a cog in the wheel of industry, yet photographers like Lewis Hine revealed the beauty of line and composition by a worker doing something so common as using a wrench to turn a bolt. When Ford's enormous River Rouge Plant opened in 1927 to produce the Model A, the painter / photographer Charles Sheeler was chosen to photograph it. The world's largest car factory captured the imagination of Sheeler, who described it as the most thrilling subject he ever had to work with. The artist also produced oil paintings of the plant, giving them titles like American Landscape and Classic Landscape.

Roots of Engineering Humanism

Long before Hine and Sheeler, other photographers and painters too had seen the art and humanity in works of engineering and technology. This is perhaps no more evident than in the Coalbrookdale Museum of Iron, located in England, where iron, which was so important to the industrial revolution, was worked for more than 400 years. Here, in the late 18th century, Abraham Darby III cast on the banks of the Severn River the large iron ribs that formed the world's first iron bridge, a dramatic departure from the classic stone and timber bridges that dotted the countryside and had been captured in numerous serene landscape paintings. The iron structure, simply but appropriately called Iron Bridge, still spans the river and still beckons engineers, artists and tourists to gaze upon and walk across it, as if on a pilgrimage to a revered place. The Coalbrookdale Museum is crowded with portraits of Iron Bridge.

At Coalbrookdale, the reflection of the ironwork in the water completes the semicircular structure to form a wide-open eye into the future that is now the past. One bucolic depiction shows pedestrians and horsemen on the bridge, as if on a woodland trail. On one shore a pair of well-dressed onlookers interrupt their stroll along the riverbank, perhaps to admire the bridge. On the other side of the gently flowing river, a lone man leads two mules beneath an arch that lets the towpath pass through the bridge's abutment. A single boatman paddles across the river in a tiny tub boat. He is in no rush because there is no towline to carry from one side of the bridge to the other. This is how Michael Rooker saw Iron Bridge in his late 18th-century painting. A colored engraving of the scene hangs in the nearby museum, along with countless other contemporary renderings of the bridge in its full glory and in its context, showing the iron structure not as a blight on the landscape but at the center of it. The surrounding area at the same time radiates out from the bridge and pales behind it.

In the 19th century, the railroads captured the imagination of artists, and the steam engine in the distance of a landscape became as much a part of it as the herd of cows in the foreground. The Impressionist Claude Monet painted railway stations (La Gare Saint-Lazare) and cathedrals (Rouen), as well as water lilies. Portrait painters such as Christian Schussele found subjects in en-

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gineers and inventors (Engineering, May–June 1994), as well as in the founding fathers of our country. By the 20th century, engineering, technology and industry were very well established as subjects for artists.

Engineered Object as Subject

American-born Joseph Pennell illustrated many European travel articles and books, including, among the many with his wife, Elizabeth Robins Pennell, Over the Alps on a Bicycle. Pennell, who early in his career made drawings of buildings under construction and shrouded in scaffolding, returned to America late in life and recorded industrial activities during World War I. He is perhaps best known among engineers for his depiction of the Panama Canal as it neared completion and his etchings of the partially completed Hell Gate and Delaware River bridges. He titled his rendering of the Philadelphia bridge, then the longest suspended span in the world and now known as the Benjamin Franklin Bridge, The Ugliest Bridge in the World, showing that he was no mere booster for technology. The validity of his extreme aesthetic assessment of the structure was supported by the great bridge engineer Gustav Lindenthal, who found the ill-proportioned and squat towers wanting in their design. That is not to say that either Lindenthal or Pennell had no regard for the project. Pennell has often been quoted as saying, "Great engineering is great art," a sentiment that he expressed repeatedly. He wrote of his contemporaries, "I understand nothing of engineering, but I know that engineers are the greatest architects and the most pictorial builders since the Greeks.…" Where some observers saw only utility, Pennell saw also beauty, if not in form then at least in scale. He felt that he was not only rendering a concrete subject but also conveying through his drawings the impression that it made on him. The sensation that Pennell felt before a great construction project he called "The Wonder of Work." He saw engineering as a process. That process is memorialized in every completed dam, skyscraper, bridge or other great achievement of engineering.

If Pennell experienced the wonder of work in the aggregate, Lewis Hine focused on the individuals who engaged in the work. Hine was trained as a sociologist but became best known as a photographer who exposed the exploitation of children. His early work documented immigrants passing through Ellis Island, along with the conditions in the New York tenements where they lived and the sweatshops where they worked. His depiction of child labor in the Carolinas brought to public attention how young children toiled for long hours amid dangerous machinery. Hine recorded American Red Cross relief efforts during World War I and, afterwards, the burden war placed on children. Upon returning to New York, he was given the opportunity to record the construction of the Empire State Building, which resulted in the striking photographs that have become such familiar images of daring and insouciance. He put his own life at risk to capture workers suspended on cables hundreds of feet in the air and sitting on a high girder eating lunch. To engineers today, one of the most striking features of these photos, published in 1932 in Men at Work, is the absence of safety lines and hard hats. However, perhaps more than anything the photos evoke Pennell's "wonder of work" and inspire admiration for the bravery and skill that bring a great engineering project to completion.

Alfred Stieglitz, who intended to study engineering at the Berlin Polytechnic, redirected his interests to photochemistry after he acquired a small camera, and while still a student he began to work to gain recognition for photography as an art form on a par with painting. His early work showed steady technical innovation, including making photographs in snow, rain and nighttime conditions. He is considered the father of modern photography as an art form. In addition to making a series of 400 prints of his wife, Georgia O'Keefe, and also 400 prints of cloud patterns related to emotions, Stieglitz captured with his camera memorable images of New York's Flatiron Building and other structures. (O'Keefe herself, so well known for her abstract floral forms and Southwestern themes, painted views of the East River, dominated by rooftops and industrial smokestacks, and the Brooklyn Bridge that crosses that river.)

Edward Steichen, another pioneer in photography as an art form, was attracted to both the glamour of Hollywood (Greta Garbo and Charlie Chaplin were two of his subjects) and the squalor of the battlefield. He led the photography division of the Army air service in World War I and headed the Navy photography unit in World War II. As director of the photography department of the Museum of Modern Art, he organized The Family of Man exhibition in 1955, a landmark fusion of art and humanity. Steichen also photographed the Flatiron Building.

Joseph Stella, largely known for painting abstract floral themes (aquatic life and jungle foliage), returned throughout his life to the subject of the Brooklyn Bridge and abstracted much of New York City in his paintings. The East River and Brooklyn Bridge also captured the imaginations of the poets. In his Crossing Brooklyn Ferry, Walt Whitman wrote about the river scene that so many commuters saw each day. He was one of them, and he reveled alike in the sunset and the ships in the harbor and the contrast of the foundry chimneys against the sunset. When the Brooklyn Bridge replaced the ferry, it also succeeded it as an inspiration to poets such as Hart Crane, whose book-length poem The Bridge is perhaps the best known.

Engineering or Architecture

Although many painters, photographers and poets have seen art and humanity in the products of

Burstein Collection / Corbis

Figure 1. Engineering and the arts and humanities have at times been viewed as antithetical by some, yet the products of engineers have often been the subjects of artists. Claude Monet, for example, was drawn to paint railroad stations, such as La Gare Saint-Lazare, shown here.

engineering and technology, not all artists have. The late 19th-century Parisian artistic and literary community found the Eiffel Tower "an offense to good taste," and characterized it as coming from the "baroque, mercantile imaginings of a machine builder." That builder, Gustav Eiffel, defended his wrought-iron tower as "beautiful in its own right" and defended the works of engineers generally:

> Can one think that because we are engineers, beauty does not preoccupy us or that we do not try to build beautiful, as well as solid and long lasting structures? Aren't the genuine functions of strength always in keeping with unwritten conditions of humanity?… Besides, there is an attraction, a special charm in the colossal to which ordinary theories of art do not apply.

Indeed, an engineer designing a structure is not unlike an artist painting one. Both start with nothing but talent, experience and inspiration. The fresh piece of paper on the drawing board is as blank as the newly stretched piece of canvas. And the greatest of bridge engineers, especially, have quite explicitly written and spoken of the aesthetic criteria and human values that influenced the shape, form, texture and function of their structures; the spans themselves stand as tributes to the successful application of their ideals.

Iron Bridge was only the first in a long line of cast-, wrought-iron and steel structures that have continued to grace the British landscape. Although the form of Iron Bridge was borrowed from the ancient lines of stone and the details from the classic lines of timber construction, it did not owe its structural success to their principles. In particular, the strength of iron in both tension and compression enabled subsequent bridges to be built with much lower profiles, thus at the same time marking them as modern and making them more user friendly. Thomas Telford was one of the first masters of the shallow arch bridge, with his 1814 Craigellachie Bridge over the River Spey near Elgin, Scotland, being an outstanding surviving example. The crossed struts between the thin arch and equally thin deck give the bridge a transparency and accessibility unknown in stone structures. The crenellated towers of the abutment, Telford's acknowledgment of the setting into which the bridge might otherwise have appeared to be an intruder, tie it into the culture of its place. Telford used a similar architectural motif on his Conwy Suspension Bridge, in deference to the Welsh castle to which it leads. Of course, Telford looked well beyond castles for his inspiration. His 1826 Menai Bridge married massive stone towers, which appear to have evolved naturally from the piers under the approach spans, with wrought-iron chains to produce a profile of near-perfect proportions that served as an aesthetic model for suspension bridges well into the 20th century.

The Brooklyn Bridge, completed in 1883, is almost three times as large as the Menai, and during construction its towers dominated the New York

Christie's Images / Corbis

Figure 2. In Men at Work, Lewis Hine focused his camera on the workers who made the Empire State Building a reality.

City skyline. The technical challenge that John Roebling faced in spanning the East River was to design a structure that would not interfere with shipping. This demanded not only a high roadway beneath which tall-masted ships could pass but also a great span to provide a wide unobstructed channel. Suspension bridges were Roebling's forte, but the combination of constraints in New York called for one of unprecedented length and height. Rather than design a purely utilitarian structure, he produced a masterpiece. The tall stone towers pierced by the twin Gothic arches through which traffic passes are necessarily massive, but their monumental design makes them feel architecturally right. Roebling's patented steel-wire cables hang with a well-proportioned sag, counterpointed by the taut diagonal cables that the engineer included out of respect for the wind and what it could do to an unstayed bridge deck. The bridge deck was designed not only for horses and carriages but also for people, and the elevated walkway that puts the walkers above the road traffic makes the bridge at the same time a brilliant work of engineering, art and humanity.

A walk across the Brooklyn Bridge is one of the world's great pedestrian experiences. The arched towers are triumphal, not in a military but in a civil engineering sense. The diagonal stays pull the eye upward to the top of the tower and to the prominent date stone embedded near the top. The high-altitude reminder that the Brooklyn tower dates from 1875 (the Manhattan is from 1876) makes the walker feel not small and insignificant but part of a larger humanity that could erect this grand edifice with little more than muscle and steam power. To stroll the walkway of the Brooklyn Bridge is to experience the dynamic nature of the bridge itself, with the suspension cables first dipping down to meet the walker at mid-span and then rising up again with the spirit to the tower top. The skyscrapers of lower Manhattan appear through the screen of steel as a great backdrop for the bridge itself. It is so grand in its execution that it is easy to forget that the bridge was built for the city, not the city for the bridge. Until last year, the twin towers of the World Trade Center dominated the view and appeared to be inspired by the bridge itself, echoing its twin arches in more modern lines. The bridge's empty arches now serve as reminders of what was once a different skyline, but seeing the sun setting through the bridge's network of stone and steel is still as dramatic an event as watching it over any mountain or sea.

The Brooklyn Bridge is an architectural masterpiece precisely because it is an engineering masterpiece. Its engineer was its architect. Although John Roebling assigned the preparation of its presentation rendering to an assistant engineer and better draftsman, Wilhelm Hildenbrand, the bridge's lines and proportions are all Roebling's. Yet in the half–century after the completion of the Brooklyn Bridge, there was a regular tension between engineers and architects over who was responsible for designing bridges and who was needed to give their aesthetic details the monumental look everyone agreed that they required.

Engineering and Architecture

Othmar Ammann, the engineer who was responsible for the greatest number of major bridges in New York City, retained professional architects to consult on aesthetics. Ammann's first independent bridge design was a suspension span to cross the Hudson River, and he engaged Cass Gilbert, the architect of the Woolworth Building, to render views of it to show to prospective supporters of the project. In the vast majority of Gilbert's studies of the bridge towers, they are clad in stone, which in the early 20th century was still considered by many the appropriate way to express the great weight that they supported. In this case, the stone was to be only façade, however, applied over a steel skeleton that was the real means of support. Yet, when the George Washington Bridge was completed in 1931, during the Depression, the steel had to be left exposed at first to save money. It was generally thought that the stone would be added when economic conditions improved. That did not happen, of course, and the architect Le Corbusier called the structure "the most beautiful bridge in the world," one on which "the steel architecture seems to laugh."

The single simple steel arch motif—an echo of Iron Bridge—that Ammann incorporated high in the towers of the George Washington Bridge became his trademark on subsequent suspension bridge towers that he designed. He did not wish to encumber his bridges with "extraneous architectural embellishments," but he did appreciate that even his preference for minimalist design called for careful thought of shape and line. For the Bronx-Whitestone Bridge, he engaged the architect Aymar Embury II to work with Allston Dana, the engineer of design. The anchorages of the bridge especially have the look of being designed without being frilly. Their shape follows the lines of the suspension cables turning into the ground, and they give the bridge a streamlined look. In writing about his involvement in the design, Embury emphasized that although he and Dana had a free hand in the work, they were "always subject to Mr. Ammann's criticism and never out of his control." Embury left no doubt that the design was ultimately that of the chief engineer, and the bridge's structural function dictated its architectural form.

The Brooklyn Bridge may be one of the most recognizable structures on the East Coast, but the Golden Gate Bridge is the most recognizable one on the West Coast. Although there has been considerable debate over how much credit chief engineer Joseph Strauss deserves for this masterpiece, there should be little doubt that it was he who was the entrepreneurial driving force behind its construction. Strauss's first design for a bridge across the entrance to San Francisco Bay was a hybrid monstrosity with little but functionality to recommend it (Engineering, March–April 1991). It was the consulting engineer Leon Moisseiff who convinced Strauss to embrace a pure suspension bridge form, and one that would be the largest in the world when completed in 1937. The detailed design work was done by Charles Ellis, who was fired by Strauss when they had a disagreement over how much more calculation was needed for the structural design of the towers. Each of these engineers can be said to have contributed to the realization of the bridge in its basic proportions, which are defined by the height of the towers and the sag of the main suspension cables.

Like Ammann, chief engineer Strauss could ultimately have had the most to say about how the bridge looked. But Strauss seems not to have had the same aesthetic sensibility. His career had involved mostly the design and construction of bascule bridges with no claim to grace. In fact, many of them were downright ugly. The extremely graceful Arlington Memorial Bridge is sometimes attributed to him, but in fact he was only connected with its design in the capacity of consulting engineer on the one well-disguised bascule span among its many fixed arches. Fortunately, when it came time to finish the Golden Gate Bridge, Strauss did not impose his own aesthetic sense, or lack thereof, on the structure. Rather, he hired consulting architects. The one who survived working with Strauss to the end was the local architect Irving Morrow. Although the bare structure of the span does give it its essential lines, much of the appeal of the Golden Gate Bridge as a piece of art derives from Morrow's architectural "details" of faceted fascia, sleek railings and the color that the structure is painted. These finishing details add considerable interest and subtlety to what has been called the "world's largest Art Deco sculpture."

Figure 3. Brooklyn Bridge is rightly regarded as one of the world's greatest pedestrian experiences, even in the rain. (Image courtesy of Dover Americana.)

Today, one of the most innovative and influential engineers is Santiago Calatrava (Engineering, March–April 1997), who trained also as an architect. His bridges and other structures show the influence of both professions, and at the same time provide public spaces of a human scale and stand as pieces of monumental sculpture in their own right. His recently completed addition to the Milwaukee Art Museum is an excellent example. Working in the European tradition of design competitions, Calatrava has established himself as one of the most watched designers of large structures in the world. Increasingly, commissioners of bridges in America are looking to such individuals or to teams of engineers and architects, sometimes working also with artists, to develop concepts for the signature bridges that so many communities now desire. This growing awareness of the intangible added value of human space and art is sure to give us more masterpieces like the Brooklyn Bridge and the Golden Gate Bridge. They in turn will continue to be inspiring monuments to civilization and ever welcome subjects for artists of all kinds.

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