Canaletto. ***Rome: The Arch of Titus*****, 1742. The Royal Collection.**

The Ambivalence of Smoke: Pollution and Modern Architectural Historiography

JORGE OTERO-PAILOS

The idea of decorative architectural materials presupposes the existence of supporting structural materials. In architecture, we are not accustomed to think of decoration outside of its relationship to structure. This binary encompasses other terms used to describe materials, such as envelope and structure or skin and bones. Terra-cotta and steel are considered early modern architecture's emblematic decorative and structural materials, respectively. Landmark skyscrapers such as Burnham and Root's Reliance Building (Chicago, 1895) or Adler and Sullivan's Wainwright Building (St. Louis, 1891) are some of the examples commonly used to establish this canonical categorization. The dominant historical narratives of modernism, from Spiro Kostof to Leonardo Benevolo and Leland Roth, give the sense that the categorization of these materials happened suddenly, as if architects of the late nineteenth century immediately understood them as decorative and structural. In truth, the change from the premodern to the modern categorization of these materials was a slow and contentious intellectual and cultural process that took place over the entire nineteenth century and involved generations of architects, each of which tried to make sense of the new products of industrialization in their own way, often disagreeing as to the place that new materials should take within the inherited framework of architectural knowledge. Many architectural historians have been satisfied to point to the outcome of this collective and gradual transformation of architectural discourse as the origin of a new modern understanding of architectural materials circa 1880, sometimes cherry-picking buildings and portraying them as anticipatory exceptions (Paxton's Crystal Palace being among the favorites). Even when more-inquisitive historians have puzzled over why nineteenth-century architects were so slow in embracing new industrial materials as legitimate architectural materials, they have seldom questioned the narrative that the eventual adoption of these materials into architectural knowledge constituted a radical intellectual rupture with nineteenth-century architectural culture. In support of that hypothesis, some of the founders of modern architectural historiography, such as the otherwise brilliant Sigfried Giedion (1888–1968), simplistically portrayed nineteenth-century architects as intellectually damaged, caught in a contradictory existence of thinking one thing about materials and feeling another.[1]

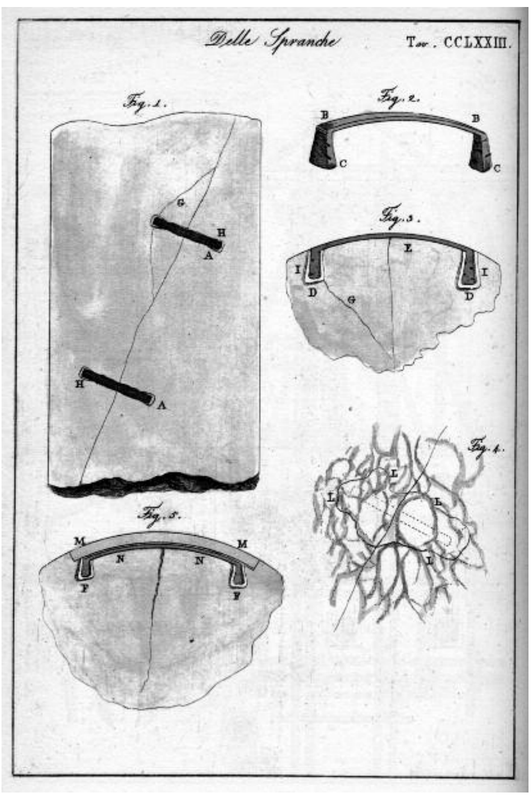
Upon closer examination, the intellectual shift in the field of architecture that was the precondition for both the categorization of new industrial materials as architectural and the subsequent emergence of modern architecture was not so much a radical rupture as a gradual and general transformation that cannot be entirely attributed to a reduced set of self-selected visionary architects or to singular events, like the construction of the Eiffel Tower or the First World War. A more complete picture emerges when we include the wider set of complex social and institutional frameworks within which architectural practice occurred. But even such an expanded sociological and institutional purview would fall short if it did not also account for the role that changing environmental conditions played in the manner in which those architects worked and thought. When considering how certain materials came to be intellectually accepted as architectural, we must not lose sight of the fact that materials were (and still are) considered fit for building partly because of their adaptation or resistance to particular environmental challenges, and those natural circumstances began to suffer perceptible alterations in the nineteenth century. As George Perkins Marsh carefully documented in his 1864 classic *Man and Nature*, by the mid-nineteenth century industrialization had already begun to change the earth's climate. As cities industrialized, the air changed noticeably as it filled with industrial smoke, and acid rain began posing new challenges to the durability of materials. Not only did architects change how they thought about building materials; the physical behavior of those materials was itself slowly changing under the action of a new and most pervasive industrial material: pollution. If material conditions play an important role in the development of human thought, without entirely determining it, then the emergence of modern architecture as an intellectual formation is hardly comprehensible without reference to environmental pollution. Under such light, the change in intellectual paradigm that we associate with modern architecture appears less as a radical shift and more a slow conceptual reorientation in response to the gradual emergence of a new, polluted environmental reality.

Right: The Arch of Titus, Rome, 71 CE. Restored by Giuseppe Valadier 1819–1821. Photo by Jorge Otero-Pailos.

Opposite: Uses of cast iron to bond together fragments of damaged buildings. From Giuseppe Valadier, *L'architettura pratica*, vol. 4 (1833).

Cement

Consider the protracted changes that led to the eventual classification of iron as a modern material. Iron had been used to build bridges since the 1770s, but neoclassical architectural theoreticians did not give metals any serious consideration as independent structural materials. For instance, Giuseppe Valadier's (1762–1839) *L'architettura pratica*, which collected his lectures delivered at the Accademia di San Luca from 1828 to 1833 into five incredibly popular volumes, primarily dealt with masonry and wood construction and did not include metals as a separate category. This was not an omission due to lack of familiarity with the material. Valadier was an expert on metals. He was the son of a goldsmith and oversaw a silver workshop where he produced his own designs for chalices and silverware. Metals did appear in his textbook, but where we least expect them, in the section on the restoration of buildings, a subject in which Valadier was also an expert. In 1805, he had restored the ancient Milvian Bridge, originally built in 115 BCE over Rome's Tiber River by consul Marcus Aemilius Scaurus. Valadier also restored the Arch of Titus in 1819–1821. His knowledge of the behavior of metals and their alloys is clear in his discussions of how to repair a cracked column. First, the worker had to drill two holes on either side of the crack. Second, he had to manufacture a staple-shaped piece of iron to fit into the holes. Once the staple was fitted, the whole area was heated. Then molten lead was poured between the stone and the iron to fill in the small space between them. He cautioned that workmen should take their time to do this job right: too much space between the iron and the stone would make the lead drip out, and too little would prevent the lead from entering the crevices and bonding the iron to the stone. Also, if the stone were not heated properly, the lead would crystallize before reaching the back of the hole.[2] Valadier gave other examples for uses of metals in architecture that always involved metal working as a cement, holding other materials together, but never simply supporting them and never supporting itself. He explained that iron worked best in tension, like a rope, which looses its structural properties when not being pulled on.[3] So he recommended iron straps to keep walls from collapsing and tie-rods to prevent arches from deforming.



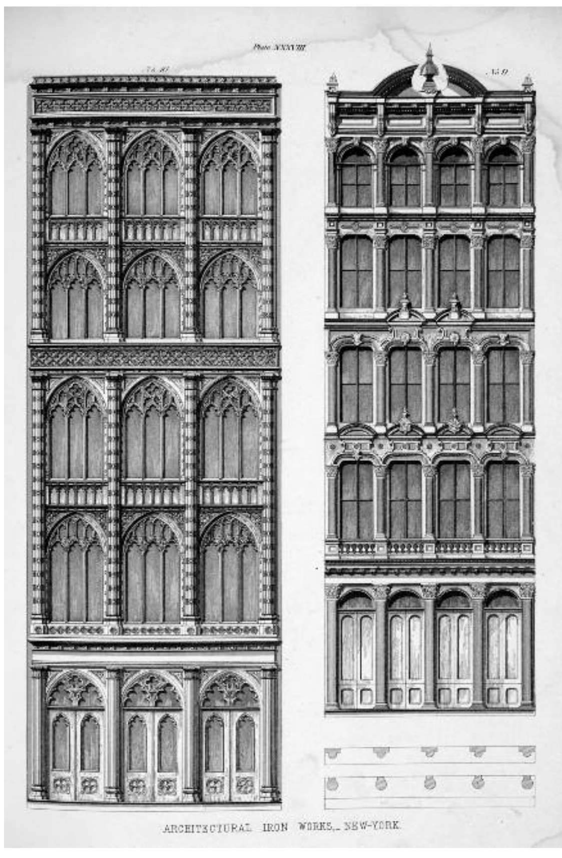
The prevailing assumption, within neoclassical architecture, that iron was a binding material, sheds some light on the reasons James Bogardus and others, when introducing cast iron as a self-supporting structural building system in the 1840s, presented it in the image of masonry construction. This was more than merely an imitative gesture. No one was fooled into believing that cast-iron buildings were actually stone. Quite the contrary, cast-iron buildings were meant to be recognized as such. A more careful reading of these early cast-iron emulations of stone reveals them to be an attempt to challenge the discursive order of architecture. They were part of an intellectual attempt to shift the classification of iron—from binding material to supporting material—by symbolically usurping the place of stone, architecture's load-bearing material par excellence.[4]

Stone

Resistance to this change was significant. Gottfried Semper's *Four Elements of Architecture* (1851) did not list metal as a primary material, limiting his theory to the classification of clay, wood, textile, and stone. John Ruskin, writing in 1849, just at the time when the first cast-iron buildings were being erected in London and New York, recognized the threat that reclassifying metals signified for the cultural order of architecture. Invoking the pronouncement of the ancient Delphic oracle, he defined iron as a "calamity upon calamity."[5] He recognized that the possibility of fully metallic construction would eventually require the development of an entirely "new system of architectural laws," something that did not happen for another fifty years.[6]

Many architects today, schooled in the modernist tradition, consider developing a new system of architectural laws to be something acceptable, even desirable. Not so for Ruskin, who insisted on the primacy of the laws of architecture developed over centuries out of the tradition of masonry construction. "Early architecture," he wrote, referring to stone buildings, particularly those in early Gothic style, "is a precious historical document" for understanding those laws.[7]

Significantly, Ruskin here introduces the word *historical*, a word that would acquire negative connotations for early twentieth-century modernist architects. But what, precisely, made it possible for architecture to be understood as historical? In Ruskin's eyes, neither the building's design, style, or date of construction made it historical.[8] Instead what

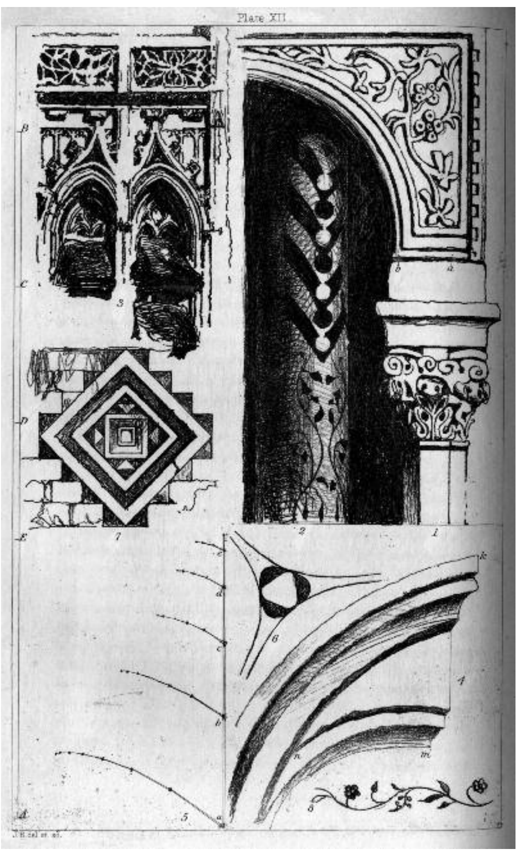


Daniel Badger. *Illustrations of Iron Architecture Made by the Architectural Iron Works of the City of New York*, 1856. Courtesy Avery Architecture and Fine Arts Library, Columbia University.

made architecture historical was first and foremost its materiality: it had to be made of masonry, preferably of good stone. Second, the stone had to be rendered as stone, made to appear as itself.

This idea of rendering stone as stone, which is one of the sources of what we have come to understand as material authenticity, requires some explanation, if only to shed light on how much of the richness of Ruskin's theorization of material authenticity has been lost. For Ruskin, as for most romantics, the source of all beauty was nature. The work in a work of architecture involved making buildings resemble nature, something entirely superfluous, he granted, to what was required of a structure. Architecture "impresses on its [building's] form certain characters venerable or beautiful, but otherwise unnecessary."[9] In Ruskin's mind, "there are only two fine arts possible to the human race, sculpture and painting. What we call architecture is only the association of these noble masses or the placing them in fit places."[10] In particular, architecture involved arranging the noble masses of stone in such a painterly or sculptural way as to evoke their natural origin. But unlike painting and sculpture, which could represent all visible forms of nature, "the characters of natural objects which the architect can represent are few and abstract."[11] Stone was one of those few natural objects that the architect could represent. Architecture involved the daunting task of making stone, after it was quarried, dressed, and assembled into a building, appear "natural" again. The architect had to treat the stone in such a way as to reveal the inner nature of the material.

Ruskin argued that, scientifically speaking, the inner nature of stone is crystalline. He maintained that the emergence of abstract decorative patterns in early Gothic architecture was an attempt by medieval masons to represent the crystalline nature of stone. But more important for our purposes, Ruskin believed that the crystalline nature of stone also revealed its historical nature. He saw stone as a unique kind of material, coming from dust that had crystallized aeons ago and, through the slow weathering action of millennia, eventually returning to dust sometime in the very distant future. The natural life of stone meant that its historical nature could not be reduced entirely to the present or simply to the moment of its assembly into buildings. In their comparatively short existence, the only insight human beings could have into the historical nature of stone was to witness its slow deteriora-



"Fragments from Abbeville, Lucca, Venice, and Pisa." From John Ruskin, *The Seven Lamps of Architecture* (1849). Courtesy the Ruskin Foundation (Ruskin Library, Lancaster University).

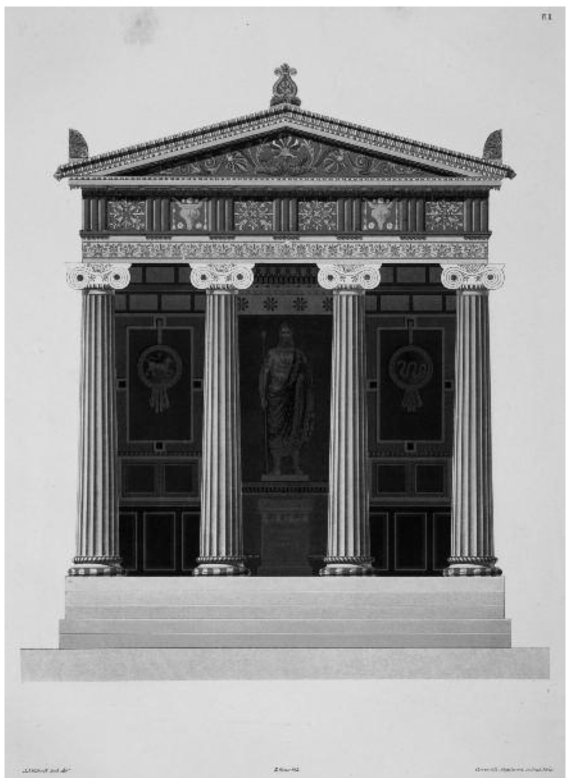
tion. So, in order to represent building stones as "natural," architects had two choices: either turn them into decorative abstract patterns evoking their crystalline nature or treat them in such a way as to make visible their slow transformation into dust.

Ruskin's opposition to painting over stones, faux finishes, and other "deceptions" was based on the fact that they would prevent the stone from decaying and therefore thwart our ability to perceive it both as natural and as historical.[12] Ruskin's theory of authenticity came on the heels of the early nineteenth-century debates over polychromy in ancient Greek temples, which involved heated discussions about whether the ancients used paint as a protective substance to prevent the weathering of stones. Jakob Hittorff (1792–1867), better known as Semper's teacher, was the primary advocate of the thesis that paint preserved ancient temples and should be used for similar protective purposes in contemporary architecture.[13]

Iron

What troubled Ruskin most about cast iron was not that it was being made to look deceptively like stone; rather, it was the fact that cast iron was crystallized through artificial means and decayed unnaturally fast, in comparison to stone. "No builder," he wrote, "has true command over the changes in the crystalline structure of iron, or over its modes of decay."[14] Iron was a manmade material, but paradoxically it escaped our comprehension, perhaps because it was too far removed from nature. When he defined iron as a "calamity upon calamity" he surely must have had, in the back of his mind, the famous 1847 collapse of the iron bridge over the Dee River at Chester, just one year after its construction, which caused five deaths and was the object of one of the first major inquiries conducted by Britain's newly formed Railway Inspectorate. If, as Ruskin maintained, the word *architecture* meant "authority over materials," then the failure to control iron, paired with the obstinate attempts to reclassify it as a support material, could only undermine the cultural order of architecture.[15] Ruskin came down hard against the reclassification of iron: "metals may be used as a *cement*," he wrote, "but not as a *support*."[16]

Today, the classification of metals as either support or decorative cladding has entirely displaced their older classification as cement. But reconstructing the kind of knowledge



Reconstruction of Temple B. From Jacques Ignace Hittorff, *Restitution du temple d'Empédocle à Sélinonte* (1851). Courtesy Avery Architectural and Fine Arts Library, Columbia University.

about architecture that this former categorization presupposed is important. Cement is a substance used to bind others together—especially, in the case of architecture, stones, bricks, or decorative ceramics. Cement is applied in a liquid or pasty state and later hardens to become as strong as the materials it holds together. More broadly, cement is "any substance applied in a soft and glutinous state to the surfaces of solid bodies to make them cohere firmly."[17]

As late as 1867, the popular *Dictionary of Arts, Manufactures and Mines* listed iron-rust and white lead as names of cements. The latter was produced by grinding white lead with linseed oil varnish and keeping it out of contact with air. White lead cement was "capable of repairing fractured bodies of all kinds. It requires a few weeks to harden. When stone and iron are to be cemented together, a compound of equal parts sulphur and pitch answers very well."[18] Iron-rust cement was

> made from 50 to 100 parts of iron borings, pounded and sifted, mixed with one part of sal ammoniac, and when it is to be applied moistened with as much water as will give it a pasty consistency. Formerly flowers of sulphur were used, and much more sal ammoniac, in making this cement, but with a decided disadvantage, as the union is effected by the oxidisement, consequent expansion and solidification of the iron powder, and any heterogeneous matter obstructs the effect.[19]

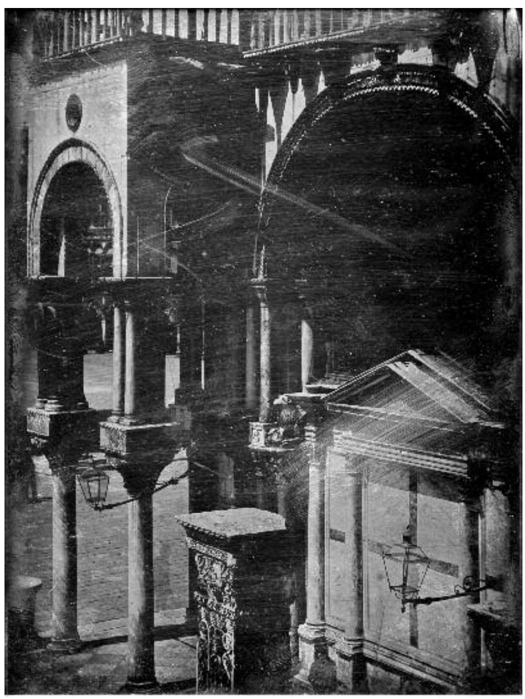
The older formula for iron cement in all likelihood refers to the formula perfected by the Swedish pharmacist Johan Julius Salberg (1680–1753) to prevent the decay of wooden buildings. In 1742, Salberg published a paper that proposed to improve on the traditional technique to coat wood with falun red (red ocher) and tar by adding iron vitriol to it. Vitriol, from the Latin *vitrum* meaning glass, was the vulgar appellation of sulfuric acid and its many compounds, which in certain states have a glassy appearance. Iron vitriol, also known as Vitriol of Mars, is the red sulfate of iron. Salberg claimed that wooden buildings coated in iron vitriol would be preserved for "eternal times." Salberg's application possibly was inspired by the fact that iron vitriol was commonly used as a disinfectant at the time. A year later, he published a paper on the application of iron vitriol to stone buildings. The case for the preservation of stone seemed less urgent than wood, so Salberg tried to sell the idea by placing more emphasis on the aesthetic effects, rather than the material conservation effects, resulting from the application. When mixed with white lime, iron vitriol produced a pleasing ocher tint and could be used to replace the much more expensive imported ocher pigments being used to coat building façades, as was fashionable in Stockholm at the time. When applied directly on stones, iron vitriol darkened them, making them appear older than they really were but also presumably protecting them from further decay.

The use of iron vitriol in architecture was a further element in Ruskin's abhorrence of iron as a "calamity upon calamity." Iron vitriol not only slowed the weathering of stones that Ruskin considered to be the source of their historical nature; it added insult to injury by artificially accelerating their aging through deceptive aesthetic means.

In the late 1870s, reports arrived in London that Giovanni Battista Meduno (1800–1880) had been slowly restoring St. Mark's Basilica, one of Ruskin's favorite buildings. Since shortly after the 1866 incorporation of Venice into the Kingdom of Italy, Meduno had been quietly replacing the old, time-stained stones of the southern wall with new, clean ones. Ruskin was appalled, and William Morris embarked his British Society for the Protection of Ancient Buildings (SPAB) on its first international campaign: to shame the Italian government into stopping the restoration.[20] A reporter for the *American Architecture and Building News* could not understand all the fuss. If the new stonework "jars the sense of color," he wrote, couldn't the problem be easily solved with a sulfate of iron wash over the new parts to "harmonize the color" with the old?[21]

One can imagine how distressed Ruskin would have been reading that article. If the ability to think about architecture as a historic object was contingent on the capacity to witness stone slowly turning into dust, then the application of iron vitriol to stone, or of any paint for that matter, severely restricted, even negated, the historicity of architecture. Under a protective coat of iron vitriol, buildings appeared suspended in time, propelled outside of nature and its weathering processes, preserved for eternity perhaps, but at the cost of becoming entirely artificial. Painting buildings severed them from nature and therefore from the source of all beauty and historicity.

Upon closer examination, the heated debates about color that haunted Western architectural discourse during the nineteenth century were really not so much about color but about more fundamental questions of how to measure the authenticity of materials in light of their natural properties of decay, how to grasp decay as an index of the temporal nature of architecture, and, by extension, how to think of architecture as a historical object. Natural decay was the rallying cry of the romantic assault on academic neoclassical architecture and on the image of architecture as a timeless, ahistorical object embalmed in paint. More important, decay was



the enabling element of a new conception of architecture's historical content and significance. Instead of the neoclassical model, in which architecture's historical content was a function of its formal, external reference to classical precedents, the romantic model conceived of architecture's historical content as a natural property of the building itself, something entirely internal: its ability to physically age. Today we can easily grasp this insight, especially after Aloïs Riegl's (1858–1905) theorization of the emergence of age value as a modern form of architectural appreciation.[22] But without the benefit of hindsight, nineteenth-century architects could only grope—half-consciously, as they forged it—toward the new sense of the historical.

As with the case of iron, this new conception of the historical was structured by, and also served to structure, the classification of new industrial materials into the existing cultural order of architecture; that is, into the complex of intellectual, social, aesthetic, and institutional frameworks, and their environmental circumstances, that sustained architecture as a legitimate practice, authorized particular buildings as works of architecture, and

Opposite: John Ruskin and George Hobbs. *Venice, Southern Portico of the Basilica of St. Mark, View from the Loggia of the Ducal Palace*, 1842. Daguerrotype. Courtesy the Ruskin Foundation (Ruskin Library, Lancaster University).

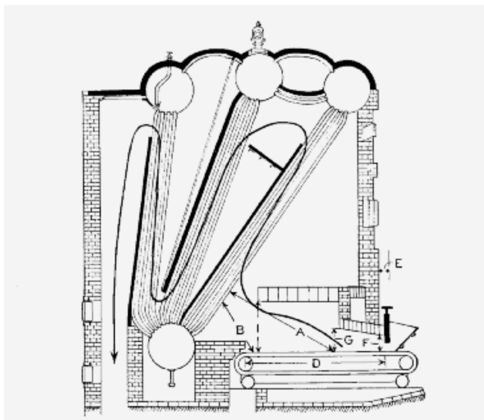
Right: Cleaned exterior of the Basilica of St. Mark, 2009. Photo by Jorge Otero-Pailos.

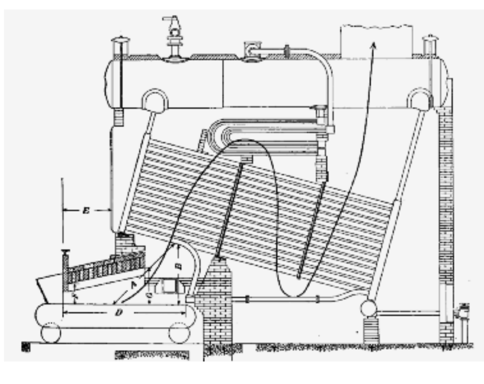
constituted their cultural "value" at any given historical moment. Every time industry introduced a new material, the cultural order of architecture was put to the test and rendered visible, as architects debated whether the new material should be granted a rightful place within the discipline. In the mid-nineteenth century, the cultural order of architecture appeared structured around the question of defining the historical nature of buildings as a function of the decay of stone. That order would be quickly put to the test by the appearance of a new and ambiguous material.

Smoke

Smoke was the most common material produced by nineteenth-century industry; it was proudly portrayed belching out of smokestacks in postcards and city views, a visible sign of progress. But, in truth, smoke was as much reviled as it was celebrated. For instance, in Pittsburgh, a place with such an intense amount of airborne pollution that it earned the moniker of "The Smoky City," generations of citizens fought a fruitless 140-year battle to force industrialists to use clean-burning furnaces. As early as 1804, the burgess of Pittsburgh had proposed a smoke control ordinance related to the height of chimneys. The little progress generations of citizen's groups had made in regulating smoke was reversed in 1939 when the city council abolished the Bureau of Smoke Regulation to lower the costs of manufacturing supplies for the Allies.[23] For all practical purposes, the sun did not shine in Pittsburgh for close to a century, as photographs amply demonstrate.[24] Sunlight returned to Pittsburgh only with the collapse of America's heavy industry in the 1960s.

The systemic failure of government regulation was just as dire in the United Kingdom. As early as 1843, the government created a Select Committee on Smoke Prevention, and by 1853 it passed the Smoke Nuisance Abatement (Metropolis) Act, which required that all new and old furnaces be made to "consume or burn the smoke arising from such furnace."[25] By the end of the 1850s a majority of English industrial towns had anti-smoke legislation in effect, including Birmingham, Derby, Huddersfield, Leeds, Newcastle-upon-Tyne, Leicester, Liverpool, and Manchester. But the legislation was laxly enforced, and enforcement bodies were understaffed. In Liverpool, for instance, a single mechanical engineer and his assistant were responsible for looking after the entire city's smoke nuisances.[26] Some towns, such as Leeds, exempted





Right: Smokeless industrial coal boilers. From D.T. Randall and H.W. Weeks, *The Smokeless Combustion of Coal in Boiler Plants*, *U.S. Geological Survey Bulletin 373* (1909).

Opposite, top: Child with rickets, as a result of vitamin D deficiency due to lack of sunlight. From Fred Grundy, *A Handbook of Social Medicine* (1947).

Opposite, bottom left: Pittsburgh under a cloud of industrial smoke, 1913. Courtesy the Carnegie Library of Pittsburgh.

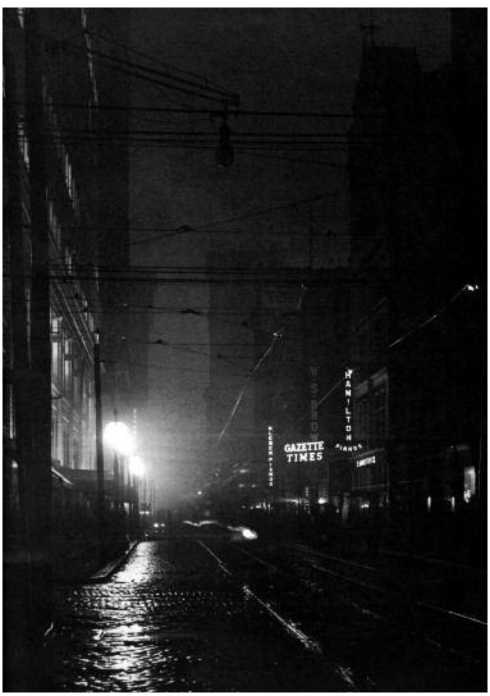
Opposite, bottom right: A Pittsburgh street at 11:00 A.M. with the sun obscured behind a cloud of industrial smoke, 1945. Courtesy the Allegheny Conference on Community Development.

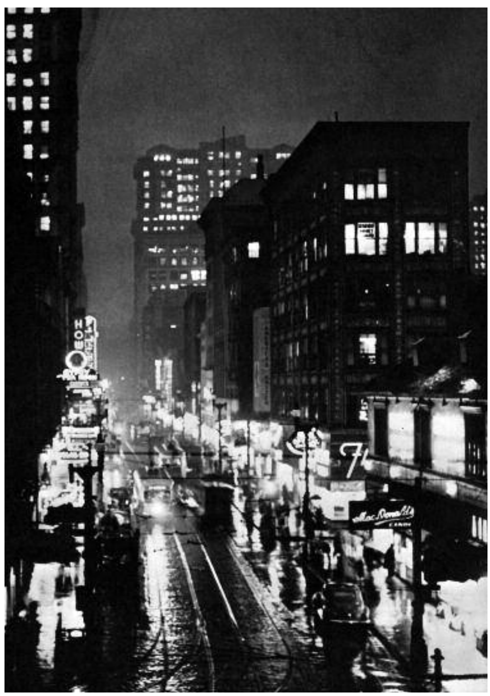
the furnaces that fueled their main businesses and produced the most smoke. The irony was not lost in an 1866 report: "The two local Manchester Acts of 1844 and 1851 have been in force since those days, with what result anyone knows who has lived in Manchester."[27] Smoke not only prevailed but actually intensified in the course of the nineteenth century, becoming the ambivalent symbol of industrial modernity, signifying at once progress and everything that was noxious about modernization.

The appearance of a permanent cloud of smoke over cities would fundamentally transform the cultural order of architecture even if (or, precisely because) architects could find no place for it within the framework of architectural knowledge. Smoke had a significant and most immediate physical impact on architecture. Whereas ancient stone buildings had taken generations to acquire the darkened surface that Ruskin praised as a dusty "time-stain," after the advent of industrial smoke buildings became stained in a fraction of the average human lifespan. By the mid-nineteenth century, the

age of buildings in London, Pittsburgh, and other industrial cities could no longer be indexed simply by the color of their patina. Was the stone time-stained or smoke-stained? Was its darkened surface the work of nature or culture? This new ambiguity caused a fundamental upheaval in the romantic cultural order of architecture, and struck fatally at the material core of its theory of architecture's authenticity and historicity.

A letter sent to London's *Times* in 1886 summed up the shift in architecture's cultural order. The author ridiculed Ruskin's idea that "the touch of a broom might injure the 'tone' of the dust" in St. Mark's Basilica and concluded that all the efforts to preserve the time-stains on buildings were as ridiculous as "to petition the Lord Mayor that the soot may not be removed from Westminster Abbey."[28] One of the apocryphal founding moments of Italian restoration theory was when Camillo Boito (1836–1914) symbolically challenged





Ruskin and SPAB by spitting on his white handkerchief and rubbing it on the walls of St. Mark's in order to demonstrate that the coloring of the stone was not due to natural decay but to soot. "We must scrupulously and religiously respect the color of time," he wrote, but it must not be confused with "extrinsic, superficial and casual soot."[29] By the 1880s, the regular cleaning of Italian monuments became a professionally sanctioned practice. Encrusted dust had gone from being interpreted as the natural temporal content of architecture, and therefore intrinsic to what made buildings historical, to being understood as industrial soot and consequently extrinsic to their historical significance.

Smoke also became a constant and central subject of concern and debate in the broader architectural discourse of the late-nineteenth and early-twentieth centuries. Smoke changed how cities were conceived. For example, Ebenezer Howard's "Slumless, Smokeless Cities" (1898) and Toni Garnier's *Cité industrielle* (1904) separated cities into functional zones and placed industry downwind from administrative and housing quarters. Less well understood is the way in which smoke fundamentally transformed architectural thinking about history, material authenticity, and aesthetics.

A representative example of how the cultural order of architecture began slowly to change when architects started attempting to make sense of smoke can be found in the address of Alfred Waterhouse, architect and president of the Birmingham School of Art, to the faculty and students on the occasion of its 1883 annual meeting. Architectural education and design had to change, argued Waterhouse, in order to adjust to the new smoky environmental conditions. The British, he feared, had "shut out the glorious sun well nigh entirely from our daily lives," and they rested "supinely under the gloomy pall by which the smoke demon obscures him from our view."[30] The new "gloomy sky" created a new modern perceptual condition that made detailed architectural decoration hard to see. Therefore, Waterhouse argued, architects should minimize decoration and instead

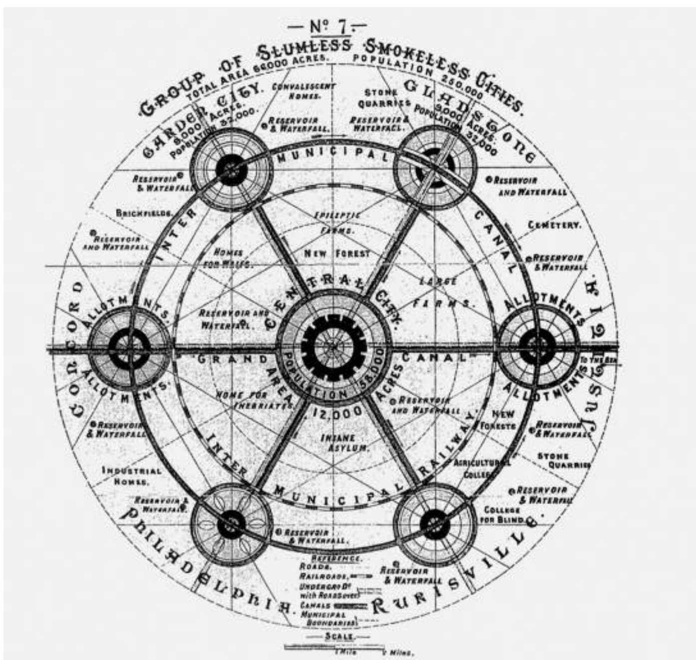


Diagram of the smokeless and slumless Ideal Garden City. From Ebenezer Howard, ***Garden Cities of To-Morrow: A Peaceful Path to Real Reform*** **(1898).**

> make much of the sky-line: They should be particular to throw their design into perspective from the various points from which it was likely to be seen, and then to shade over in monotone the building so thrown into perspective, to see that their composition would be satisfactory when silhouetted against the sky.[31]

Waterhouse's protomodernist demotion of decoration and his theorization of the skyline link the early history of both of these key modernist ideas to the effects of pollution on human perception. If modernity is the human experience of modernization, and modernism its cultural expression,[32] then Waterhouse casts light on the central role that pollution played in shaping the aesthetic discourse of modern architecture.

Waterhouse was a founding member of the British Smoke Abatement Society.[33] While the society desperately and fruitlessly tried to have smoke laws enforced, Waterhouse worked in parallel on more pragmatic initiatives to adapt architectural production to the new reality of a smoky environment. Industrial smoke, he argued, had made traditional building materials obsolete, especially stone. "We found," wrote Waterhouse, "all our best building-stone more or less yielding to the acids which were generated with the smoke which environed us."[34]

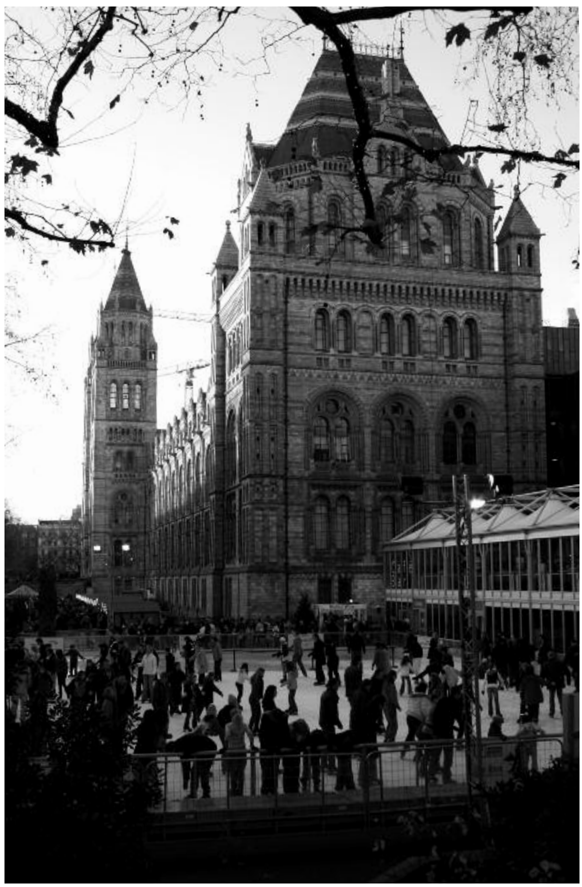
One cannot overemphasize the architectural crisis that smoke caused when it began to make stone, the architectural symbol of stability and endurance, essentially dissolve or (to paraphrase Marx and Engels, Waterhouse's contemporaries) "melt into air." By the early 1880s, the cultural order of architecture had become unhinged: the historic nature of architecture could no longer be defined in terms of the slow decay of stone into dust, as the romantics had done earlier in the century. Not by coincidence, that moment of crisis was when art historians turned their attention to architecture in earnest, with a sense of renewed interest, in search of answers to the question, what makes architecture historical? The historiographical experiments that founded modern architectural history, from Hippolyte Taine's (1828–1893) late works on contextualist determinism to Heinrich Wölfflin's (1864–1945) youthful writings on empathic expressionism, began as schematic responses to the crisis. Between the radical poles of Taine and Wölfflin, mainstream architectural history for the most part developed as a bland antiquarianism that sought to equate style with the historic content of architecture. Antiquarianism provided intellectual support for the late-nineteenth-century architectural aesthetics we call eclectic historicism. Conversely, antiquarianism would not have found a foothold in architecture without a material support: industrial terra-cotta, a cheap substitute for carved stone, lightweight enough to be shipped great distances economically and durable enough to outperform stone under the acids of industrial smoke, made the profusion of richly ornate masonry façades possible in every historical style imaginable.

Terra-cotta

The history of terra-cotta's recategorization from a traditional to a modern material attests to the fact that with the recognition of the destructiveness of smoke the modernization of architecture became, paradoxically, synonymous with finding ways to control the damage caused by modernization on buildings, especially stone buildings. As in the case of iron, the possibility of thinking of terra-cotta as modern hinged on its ability to symbolically replace stone. But whereas iron was cast as a better load-bearing material than stone, the profession's endorsement of ornamental terra-cotta was based on the recognition that it could be made more resistant to acid rain, as we now call it.

Like iron, terra-cotta had been around since ancient times, having been mostly used in pottery and sculpture but also in some building applications such as ornamental bas-reliefs and roof tiles. Attempts to classify it as a modern material were therefore not obvious or immediately accepted. The introduction of industrial terra-cotta in the 1860s provided a new level of precision, regularity in dimensioning, and volume of production that smaller, traditional kilns could not attain. But at the outset, terra-cotta factories remained comparatively small. Large terra-cotta buildings had to be supplied by multiple manufacturers, which created coordination and dimensioning problems at the construction site.

A daring innovator, Waterhouse sought to solve these problems by assigning the terra-cotta contract for his Natural History Museum (London, 1873–1881) to a single company, Gibbs and Canning, which manufactured every element of the enormous 680-foot-long building. More important, Waterhouse chose to make the entire façade almost monochrome, eschewing the sharp color contrasts fashionable in the material palette of Gothic buildings of the high Victorian period, which often juxtaposed cream-colored limestones and brown or reddish sandstones or brick. Anticipating that his building would soon turn black from London's airborne pollution, Waterhouse



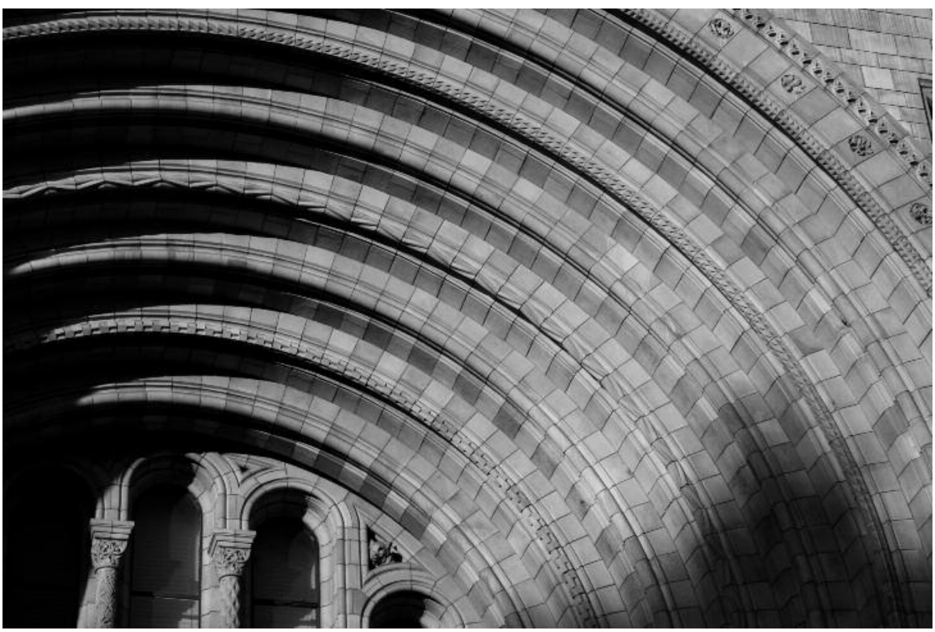
Right: Alfred Waterhouse. Natural History Museum, London, 1873–1881. Photo by Jorge Otero-Pailos.

Opposite: Alfred Waterhouse. Natural History Museum, London, 1873–1881. Photo by Jorge Otero-Pailos.

settled on a combination of muted-brown and blue-grey terra-cotta, the latter of which was achieved by adding a coating of cobalt slips to the clay slabs before firing them. The museum curators were quick to criticize the monochrome color, fearing that its old bone-like tone would detract from the visual impact of their skeleton collections.[35]

Waterhouse's choice of warm buff terra-cotta had the advantage that it could be made of a single type of clay, fired once just as it left the mold, without any finish or undercutting by hand. Other major British architects, like George Gilbert Scott, also preferred this bricklike finish for terra-cotta, partly because it could be combined with bricks fired of the same clay. The downside was that the color of the terra-cotta could not be standardized, because it would vary slightly from piece to piece according to the natural color variations of the clay pit. British architects tended to accept variations in the final shade and color as artistic rather than reject them as manufacturing defects. But the inability to provide predictable, standard colors, and the strong association with traditional brick construction, stood in the way of Waterhouse's attempt to recategorize terra-cotta as a modern material.

The decisive shift toward a new understanding of terra-cotta as a modern material occurred thanks in part to the efforts of James Taylor, an architect and industrialist known as the father of the American terra-cotta industry. Taylor advocated glazing terra-cotta, inspired by ancient faience techniques, as a way to make it more resistant to acids and also to guarantee standardized color matching. Glazed terra-cotta was more expensive to make because it required firing the clay twice, first in biscuit form and then again at a lower temperature, after a glaze had been applied, in order to vitrify its surface. Multiple clays had to be mixed into the paste in order to guarantee chemical compatibility with glazes. The color of the clay itself was no longer important because it would be covered over by the glaze. This also freed manufacturers from dependency on a single clay supplier for each job and helped to bring down costs. By glazing terra-cotta, manufacturers were able to bake a permanent protective layer of color onto the masonry, a technique that Hittorff would have understood as a great advance over covering



new stone buildings with iron vitriol or paint. Taylor succeeded in persuading American clay workers to subscribe to the compound glazed approach by touting the smoke resistance of the resulting terra-cotta.[36]

Without the introduction of cheap glazed terra-cotta, Daniel Burnham's White City at the 1893 Chicago World's Fair, with its lavishly sculpted Beaux-Arts façades, would have been too expensive a proposition to be taken seriously as a model for the modern American city. The fair's temporary buildings were famously made of inexpensive stucco, imitating white marble. Strategically located away from Chicago's smokestacks, the fair allowed visitors to experience a futuristic city without smoke, in which buildings appeared resplendent, in sharp contrast to the soiled skyscrapers of downtown. On that count, the fair provided the first real glimpse of the smokeless city that hygienists such as the British physician Benjamin Ward Richardson (1828–1896) had envisioned twenty years earlier. Richardson's immensely popular book *Hygeia: A City of Health* (1876) was a source of inspiration to urban planners well into the twentieth century. Hygeia's most "radical change," he wrote, was to enforce the use of smokeless chimneys,

> all connected with central shafts, into which the smoke is drawn, and, after being passed through a gas furnace to destroy the free carbon, is discharged colourless into the open air. The city, therefore, at the expense of a small smoke rate, is free of raised chimneys and of the intolerable nuisance of smoke.[37]

Richardson's futuristic city called for using smokeless furnaces, a technology that was more than a quarter-century old at the time he was writing and that industrialists had resisted implementing on account of its costs. He also proposed that all houses be built of glazed brick, inside and out, so as to prevent the accumulation of encrusted soot.

Richardson's most important contribution was in helping to change the definition of smoke from a "nuisance" into a health hazard by decisively linking it to health and mortality rates: "That large class of deaths from pulmonary consumption," he wrote, "induced in less favoured cities by exposure to impure air and badly ventilated rooms, would, I believe, be reduced so as to bring down the mortality of this signally fatal malady one third at least."[38] The vernacular language and tone of *Hygeia* helped to raise awareness about the toxicity of smoke and armed the public with medical arguments. Finally, in 1883, the Select Committee on Smoke Nuisances reported that the ever-

Right: Burnham and Root. Reliance Building, Chicago, 1889–1895, as it appeared soon after construction. Library of Congress, Prints and Photographs Division, Historic American Buildings Survey Record ILL 16-CHIG, 30-2.

Opposite, left: The soiled terra-cotta façade of the Reliance Building in the 1970s. C. William Brubaker Collection, University of Illinois at Chicago.

Opposite, right: The cleaned terra-cotta of the Reliance Building after its restoration in the late 1990s by Gunny Harboe. Photo by Jorge Otero-Pailos.

intensifying cloud of "fog" over London was as lethal as any epidemic.[39]

Smoke was the enabling element for terra-cotta's reclassification from a traditional material to a modern one. Not only was terra-cotta resistant to smoke acids, as Waterhouse argued, the layer of glazing allowed American journals to tout it as the first self-cleaning material.[40] While keeping marble, limestone, and granite buildings clean was costly, glazed terra-cotta buildings would be washed down by every rainstorm. Terra-cotta could be made to imitate most building stones and sculpted at a fraction of the price. But a glaze to imitate the white marble for Burnham's futuristic White City turned out to be one of the most difficult to produce. The race to find an affordable white glaze would make the subject of a fascinating industrial espionage novella. Glaze chemists were notorious for keeping their formulas secret as leverage against their employers. The Gladding McBean Company spurned any advice from Taylor for developing a white glaze at a single firing, turning instead to the promise of scientific transparency offered by Professor Edward Orton Jr. (1863–1932), first chairman of the department of Ceramic Engineering at Ohio State University. But it was industrialist T.C. Booth who succeeded in pioneering the introduction of white glazed terra-cotta in the United Sates between 1894 and 1897.[41] His fully glazed terra-cotta was converted to the matte finish of marble by the drastic measure of sandblasting.

American architects embraced the new, marble-colored self-cleaning terra-cotta as their modern façade material of choice. Terra-cotta seemed to provide an answer to both the problem of the perishability of stone monuments and the desire for a more hygienic city. Matte-finished white terra-cotta most closely resembled the marble monuments of ancient Greece and Rome, while the glossy version was, as Joanna Merwood-Salisbury has pointed out, associated with the sanitary porcelain used in hospitals, kitchens, and bathrooms.[42] Charles Atwood (1849–1896) was an early adopter, famously changing the color scheme and design for the façade of Chicago's Reliance Building (completed in 1895) when he took charge of the project in 1891,

upon the death of John Root. Cass Gilbert also specified white glazed terra-cotta to give a modern appearance to the façade of his Woolworth Building (1911–1913), the tallest building in the world at the time. By the turn of the century, the reclassification of terra-cotta from a traditional to a modern material was complete.

Newness

Glazed terra-cotta introduced to the urban environment a new architectural aesthetics of cleanliness and shininess, which became the signature of modern architecture and paved the way for the adoption of polished and reflective industrial materials into its material palette. But in the late nineteenth century, the appeal of the clean, shiny, modern aesthetic was not simply driven by hygienic concerns. It was also appealing because it was intellectually challenging. Glazed terra-cotta allowed architects to produce a new sort of architectural object, one that could not be easily understood within the existing romantic and antiquarian frameworks of architectural knowledge. As a self-cleaning material, glazed terra-cotta promised to keep buildings looking new for the foreseeable future, if not forever, even under the aggressively soiling smoke of the late-nineteenth-century metropolis. Fully glazed terra-cotta façades like that of the Woolworth Building defied aging, defined by contemporary theorists like Riegl as a loss of form or color integrity.[43] They promised perpetual newness without maintenance and by extension without the need for preservation.

"Newness-value," wrote Riegl, "is indeed the most formidable opponent of age-value."[44] These terms were code for "restoration" and "conservation," and with them Riegl was trying to retell the story of nineteenth-century preservation without having to mention the names of Viollet-le-Duc and Ruskin. Restoration work based on newness-value involved restoring monuments to an imaginary original state, à la Viollet-le-Duc, removing baroque reredos from Gothic churches to reinstate their stylistic integrity. Conservation work based on age-value involved allowing the color of buildings to slowly darken and their form to disintegrate into dust, as Ruskin would have it.

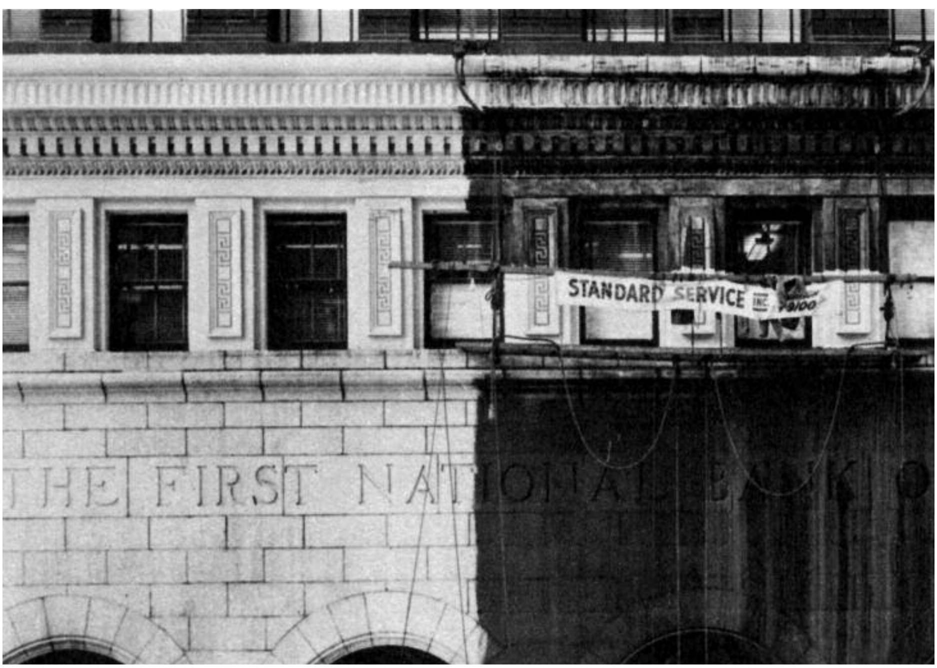
For Riegl, both newness-value and age-value were in the end attitudes toward nature. Newness-value was the attempt to emulate nature's ability to give shape and color to matter. "In this process," he wrote, "man acts just as nature does: both produce discrete and individual entities."[45] Age-value was the attempt to imitate nature's entropic force, by carefully curating the *natural* destruction of buildings, stabilizing it just enough to appreciate it aesthetically. "There must be no additions or subtractions, no substitutions for what nature has undone, no removal of anything that nature has added

Cleaning of First National Bank façade, Pittsburgh, late 1940s. Courtesy the Allegheny Conference on Community Development.

to the original discrete form."[46] Significantly, but also somewhat anachronistically, Riegl noted that age-value manifested itself most tellingly "in the corrosion of surfaces, in their patina," precisely the material layer that industrial smoke had made historiographically ambiguous.[47]

Even Riegl, one of the most incisive and intellectually advanced historians and theorists of art, architecture, and preservation of his time, could not accept that the material manifestation of newness and age was no longer simply a "natural" phenomenon. The corrosion of materials and the patination of their surfaces was not only artificially accelerated but also completely changed at both the chemical and visual levels by the introduction of industrial pollution into the air. Since the days of Waterhouse, the distinction between natural and manmade had already blurred to such a degree that even the physical and chemical action of the weather on buildings, the weathering of their surfaces, could no longer be thought of as distinctly natural. Oddly, though, Riegl's foundational text on preservation did not acknowledge the existence of pollution, even if it was already recognized as a major problem for monuments.

Glazed terra-cotta was not only a victory over nature; it was also, and perhaps more importantly, a victory over the work of humanity. Paradoxically, it came to be considered a modern material the minute its ability to mitigate the negative effects of industrialization on buildings could be proven. Insofar as glazed terra-cotta's modern classification answered the logic of technological determinism, whereby the only solution to the deleterious unintentional consequences of technology is more technology, it also allows us to see the intellectual challenge that it created for the nineteenth-century cultural order of architecture. The scientific foundation of much of that cultural order was not technology but historiography, which explains, for instance, why Riegl was placed at the helm of Austria's preservation bureaucracy. The historian, not the architect, was entrusted with the role of categorizing architectural knowledge about the material world, shaping its cultural order, and establishing the relatively enduring value of ideas to the

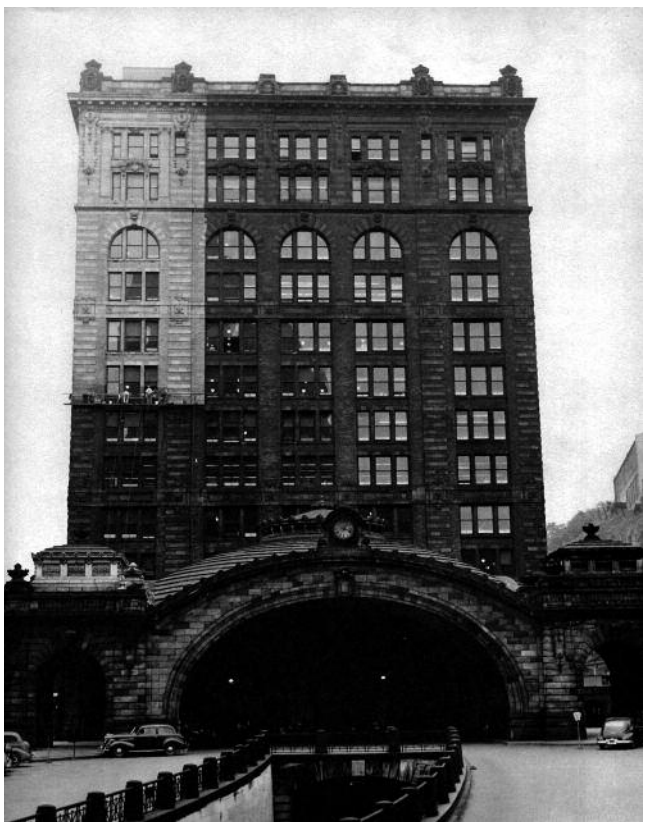


field. As much as Riegl tried to distinguish himself from nineteenth-century intellectuals, he also followed in their footsteps when he had recourse to historiographical work as the basis for decisions about how to incorporate new technologies and materials into architecture.

Yet the materiality of terra-cotta could not be gauged by the same historiographical distinction between age and newness. Its perpetual cleanliness entailed at least the hypothetical possibility that a building might never enter the "past" or that if it did it might have to do so "unnaturally"—that is, not because of its age but because it would have ceased to be useful as a technological object. Other disciplines stepped into the intellectual void left open by the inability of historians to conceptualize the aging of terra-cotta buildings and imagined a past for them similar to that of previous stone buildings. As Daniel Abramson has noted, by the 1920s American statisticians and accountants had perfected theories of financial obsolescence that justified the demolition of countless "new" steel and terra-cotta buildings.[48] A modern building could be made to conquer the weather, history, and even humanity, but not its maker, capital.

That pollution has remained such a visible concern for architects since the middle of the nineteenth century and yet has proved so invisible to architectural historians is somewhat baffling. Like some invisible force, pollution has only been graspable through its effects on other materials, such as stone, iron, or terra-cotta. But through them, it has also created the material conditions and support for radical changes in how we think about architecture. In particular, pollution helped create the conditions for the great tectonic reordering of architectural historiography from an understanding of architecture and its history as things essentially related to nature to one in which the two are seen as founded in technology. The slow but inexorable shift took about a century and involved more agents than can possibly be accounted for in this essay. But the shift was essentially complete by the time Giedion wrote *Mechanization Takes Command* (1948).

If we return to Ruskin's idea that our ability to think historically about architecture depends on our thinking through the manner of decay of materials, then we might want to ask what sort of historical thinking can grasp a form of decay that cannot be traced



Cleaning of Pennsylvania Station, Pittsburgh, late 1940s. Courtesy the Allegheny Conference on Community Development.

back to either natural or technological causes but involves an amalgam of both. In a sense everything hinges on how we classify materials, pollution in particular. If we allow ourselves to think of pollution as an independent, self-contained system that is outside of architecture proper, then we will miss the fact that our ability to conceptualize modern architecture is precisely contingent on the work of pollution on and in buildings.

Perhaps the key is to consider that architectural materials are never pure but rather composite and therefore contingent and dependent, neither natural nor artificial, posthuman in the sense that we do not have full authority over them. If we can do so, then a whole different mode of historicizing would be required in order to understand architecture, one that would bear no relation to modern historiography. Such a new historiography would emerge hand in hand with the acknowledgment of smoke and pollution as enabling materials of modern architecture, for pollution is not the opposite of nature or technology but a material that negates (in the sense that it cannot be fully grasped through) our inherited naturalistic and technologistic historiographies.

Notes

1. Sigfried Giedion, *Space, Time and Architecture: The Growth of a New Tradition* (Cambridge: Harvard University Press, 1962), 180.

2. Giuseppe Valadier, *L'architettura pratica dettata nella scuola e cattedra dell'insigne Accademia di S. Luca* (1833; Rome: Anastatica Sapere, 2000), 84–85.

3. "Il ferro devesi riguardare, come si disse colle medesime proprietà di una corda; una corda opera quando è rettamente tesa, se vi sono nodi prima di tirare si stringono; ed ecco perduta una parte della sua forza; se la corda nel tirare viene a formare per qualche urto un angolo ottuso, o tortuosità, cedendo quei punti di appoggio si allenta e più non agisce, onde se queste non sono in linea retta ovvero in perfetto corpo rotondo agiranno sempre con incertezza e male, e però non si condanni il metodo di adoprare senza abuso le catene di ferro ma piuttosto il modo di adoprar se si risultati saranno cattivi." Valadier, 93.

4. Cast-iron columns began to replace wood columns in early factories not because of their added compressive strength but because of their superior fire resistance. See William H. Pierson, *Technology and the Picturesque: The Corporate and the Early Gothic Styles*, vol. 2 of *American Buildings and Their Architects* (New York: Oxford University Press, 1978), 27.

5. John Ruskin, *The Seven Lamps of Architecture* (1880; New York: Dover Publications, 1989), 42. The first edition was published in 1849.

6. Ruskin, 39.

7. Ruskin, 218.

8. Ruskin did not consider architects to be responsible for the building's historical nature. "I saw," he wrote, "that the idea of an independent architectural profession was a mere modern fallacy, the thought of which had never so much as entered the heads of the great nations of earlier times." Ruskin, 217.

9. Ruskin, 9.

10. Ruskin, 217.

11. Ruskin, 117.

12. Ruskin, 29–69.

13. Jakob Hittorff, *Restitution du temple d'Empédocle à Sélinonte, ou l'architecture polychrome chez les Grecs* (Paris, 1851). Hittorff originally delivered the text as a lecture in Paris in 1830 before the Académie des Inscriptions under the title "Mémoire sur l'architecture polychrome chez les Grecs."

14. Ruskin, 42.

15. Ruskin, 42.

16. Ruskin, 41; emphasis in original.

17. *Oxford English Dictionary*, 2nd ed. (Oxford, UK: Oxford University Press, 1989).

18. Robert Hunt, ed., *Ure's Dictionary of Arts, Manufactures and Mines: Containing a Clear Exposition of Their Principles and Practice*, 6th ed. (London: Longmans, Green, and Co., 1867), 681.

19. Hunt, 680.

20. Frank C. Sharp, "Exporting the Revolution: The Work of SPAB Outside Britain 1878–1914," in *From William Morris: Building Conservation and the Arts and Crafts Cult of Authenticity*, ed. Chris Miele (New Haven: Yale University Press, 2005), 187–212.

21. "The Restoration of St. Mark's," *American Architecture and Building News* 7, no. 215 (1880): 46–47.

22. Aloïs Riegl, *Der moderne Denkmalkultus* (Vienna, 1903); Aloïs Riegl, "The Modern

Cult of Monuments: Its Character and Its Origin," trans. Kurt W. Forster and Diane Ghirardo, *Oppositions* 25 (Fall 1982): 21–51.

23. Stefan Lorant, *Pittsburgh: The Story of an American City* (Garden City, NY: Doubleday and Company, 1964), 375.

24. Some of the most famous photographs of Pittsburgh's smoky street scenes were taken by Arnold Rothstein, John Vachon, and John Collier in the mid-1930s for the Farm Security Administration. Another important photographic record is the one created by the Allegheny Conference on Community Development, which in 1945 commissioned photographs of Pittsburgh streets to document the effect of smoke on daily life. See Lorant.

25. Hunt, 689.

26. Hunt, 692.

27. Hunt, 692.

28. Sharp, "Exporting the Revolution," 197.

29. My translation. Camillo Boito, "Un Quesito di Lavatura," in *Questioni pratiche di belle arti: Restauri, concorsi, legislazione, professione, insegnamento* (Milan: Ulrico Hoepli, 1893), 102.

30. Alfred Waterhouse, "Lecture to Birmingham Art Students," *Building News* 44 (1883): 246.

31.Waterhouse, "Lecture to Birmingham Art Students," 246.

32. Marshall Berman, *All That Is Solid Melts into Air: The Experience of Modernity* (New York: Simon and Schuster, 1982).

33. Michael Stratton, *The Terracotta Revival: Building Innovation and the Image of the Industrial City in Britain and North America* (London: Victor Gollanz, in association with Peter Crawley, 1993), 79.

34. Waterhouse, "Lecture to Birmingham Art Students," 246.

35. Stratton, 76.

36. James Taylor, "Architectural Terracotta No. 7," *Clay-Worker* 8 (1887): 1–4.

37. Benjamin Ward Richardson, *Hygeia: A City of Health* (1876; Project Gutenberg, 2004), n.p., http://www.gutenberg.org/files/12036/12036-h/12036-h.htm.

38. Richardson.

39. "Key Dates Health and Nursing, Great Britain 1000–1899," ThePotteries.org: The Local History of Stoke-on-Trent, England, http://www.thepotteries.org/dates/health.htm.

40. *Economist* 12 (15 August 1894): 206.

41. Stratton, 24.

42. Joanna Merwood-Salisbury, *Chicago 1890: The Skyscraper and the Modern City* (Chicago: The University of Chicago Press, 2009), 106.

43. Riegl, "The Modern Cult of Monuments," 21–51.

44. Riegl, "The Modern Cult of Monuments," 42.

45. Riegl, "The Modern Cult of Monuments," 31.

46. Riegl, "The Modern Cult of Monuments," 32.

47. Riegl, "The Modern Cult of Monuments," 32.

48. Daniel M. Abramson, "Obsolescence: Notes towards a History," *Praxis: Journal of Writing + Building* 5 (2003): 106–112.