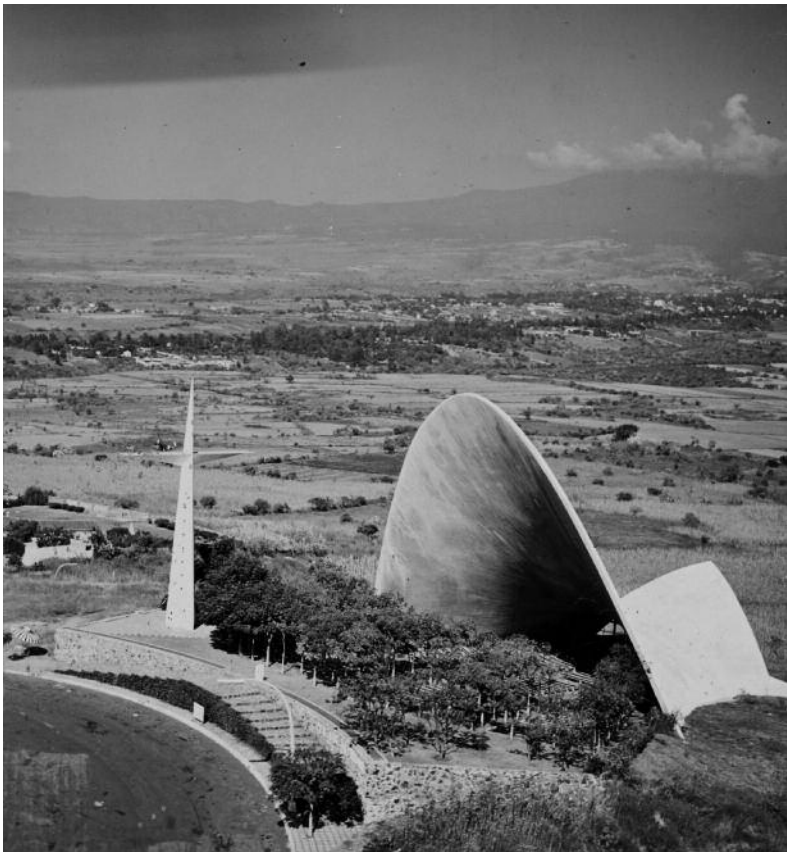


Top: Félix Candela with Guillermo Rosell and Manuel Larrosa. Open Palmira Church, Cuernavaca, Mexico, 1959. Aerial view. Courtesy Félix Candela Architectural Records and Papers Collection, Avery Drawings and Archives, Columbia University.

Bottom: Félix Candela with Guillermo Rosell and Manuel Larrosa. Open Palmira Church, Cuernavaca, Mexico, 1959. Shell under construction, 1958. Courtesy Félix Candela Papers, Manuscripts Division, Department of Rare Books and Special Collections, Princeton University Library.

 https://doi.org/10.1162/grey_a_00240

Fifty Cents a Foot, 14,500 Buckets: Concrete Numbers and the Illusory Shells of Mexican Economy

MARÍA GONZÁLEZ PENDÁS

Workers were disassembling the wooden scaffolding and formwork that supported the concrete shell of the Open Palmira Church (Capilla Abierta en Palmira) in Cuernavaca, south of Mexico City—a crucial process in the construction of structures of this type also known as decentering. At some point it became clear that the process was not going well, and workers stayed clear of the structure as they watched part of it collapse—folding in like wet cloth. Alarmed, they swiftly contacted their boss, Félix Candela, structural designer and director of Cubiertas Ala (Wing Roofs), the construction company charged with the concrete work on the site. They reported no major injuries. Candela arrived a few hours later and nonchalantly declared the company was perfectly prepared for such an incident, to the extent that Cubiertas Ala "charged double for the shells because sometimes, they fall."[1] With that, he began to instruct the workers on how to proceed with reconstruction.

The collapse occurred sometime in the fall of 1958, and by February 1959 the less-than-two-inch-thick shell of the Palmira Church stood seventy feet at its highest point, a quintessential example of Candela's signature structures. Already amounting to more than two hundred buildings for a variety of typologies, including churches, markets, warehouses, and factory plants, the thin concrete shells erected by Cubiertas Ala had by then acquired great renown both locally and abroad. In September of 1958, for instance, *Time* magazine deemed the shells "the pride of Mexico City" and Candela the "new magician of concrete," while he was called the "Wizard of the Shells" in *Architectural Forum* a year later.[2] In the decade that followed, the firm completed more than five hundred structures and received around fourteen hundred commissions. Absent from the growing recognition of the shells—including countless laudatory articles in professional journals and the general press, a monograph, a handful of prestigious international structural design prizes, and worldwide lecturing for Candela—was the story of the fall of the Palmira Church; or, more pre-

cisely, the fact that failure was at the crux of the magician's craft.

Fast-forward to 1973 and witness another of Cubiertas Ala's collapses. At 11:30 a.m. on July 4, an official of the Secretaria de Hacienda y Crédito Público (SHCP, the Mexican internal revenue service) walked into the company's offices, located in the center of Mexico City, and executed a seizure order for seven metallic desks, four filing cabinets, three typewriters, and two electric calculating machines. Three remaining adding machines were seized on the morning of October 22. They were all in impeccable condition. Estimated at just over 24,000 pesos ($1,920), the goods were meant to settle overdue "Cuotas de Obreros Patronales," the social security payments made to the Instituto Mexicano de Seguridad Social (IMSS, Mexican Institute for Social Security), which at the time mainly covered workers' medical expenses.[3] The episode was the endpoint of a financial fall long in the making, and it resolved the fate of the shells. Having filed a petition to cease operations with the SHCP in November 1970, and with only one or two projects per year from then until its last commission in 1975, Cubiertas Ala was virtually out of business after the 1973 foreclosure. By then, Candela had already parted ways with the company and moved on to an academic career in the United States after the construction of his last renowned building, the 1968 Palacio de los Deportes (Olympic Sports Pavilion) in Mexico City.[4] While the shell of the Palmira Church had risen from its rubble to lead the surge of Cubiertas Ala in the 1960s, by 1973 the collapse of the company proved the shells and their magic obsolete.[5]

Failure has long been understood as a rich repository of information in technology systems, intrinsic to processes of innovation in design and to risk in economics.[6] In the case of midcentury concrete thin-shells, the two failures that bookend their phenomenal success serve particularly well to probe the issue of cost in architecture; specifically, the cost of inventing concrete thin-shells as both an aesthetic system and a technology—that is, as objects that projected a particular image and carried out a particular process of building.[7] Crucial to the conception of shell architecture as promoted by Candela, the two collapses appear at first disparate enough. One, physical, was set on a muddy construction site; the other, financial, took place behind the closed doors of the design office. One was sudden and dramatic; the other, an unraveling at bureaucratic pace. One manifested through flawed techniques and failing materials—broken wooden planks, flying nails, and damp cement; the other, through the valuation of the pristine machines meant to calculate the structural integrity of the shells in the first place. Expenditure of means was, however, at the core of both episodes, implicit in Candela's casual comment about "charging twice" and explicit

in the financial implosion of the company. Also at the center of the two collapses were workers. While their presence was center stage at the construction site, they remained ghostly but essential during the seizure of calculating machines inside the design studio. For what was mainly at stake in the social security payments that were first in line among the company's debts were workers and the worth of their bodies.

This article draws from these two episodes of failure and their connecting threads—shell expenditure and shell workers—to chronicle the ways in which the shells buttressed a productive tension between cost, labor, and architecture—or between the economy that emerged within the shells, the social relations of labor that underpinned their construction, and the aesthetic registers they produced. Cost was essential to the consensus regarding the shells' merit both during their lifetime and in the literature that later chronicled their development. The latter, usually taking the form of reconstructions of the shell's structural and numerical integrity, seldom failed to reinforce their mystique by emphasizing Candela's genius and the economic virtue of the system.[8] Spanning large surfaces with a minimum amount of concrete, the shells stood for a model of surplus architecture wherein an excess of space is enclosed with little material. In addition, the construction process relied on low-skilled, low-cost labor to keep the shells notoriously inexpensive. According to *Time*, a shell could be built for as little as fifty cents per square foot if the program was industrial, while the monumentality required by a church raised the cost slightly, to around $41,000 per building. Then, of course, there was the image. With their soaring height, smooth white surfaces, and twisting thin planes, the shells looked at once lyrical and technological, an image-value that positioned them squarely within the regime of "architecture." As *Time* noted, Candela's shells were "not only cheap but handsome."[9]

This formula was particularly appealing to Cubiertas Ala's private clientele, but *Time* was on point when signaling the high status of the shells at a national level during the so-called miracle period of Mexican development. This corresponded to the three decades of steady economic growth and aggressive industrial development from 1940 to 1970, when the single-party state also looked to project its politics of economic progress in cultural terms. The shells served that purpose well by providing a radical image of abstract universality to the concrete construction industry—a goal assiduously sought by the avant-gardes since the Mexican Revolution—and doing so at a formidable scale.[10] As Luis Castañeda has argued, insofar as the shells turned a craft building-trade into sophisticated objects, they generated powerful images for the heroic mobilization of inexpensive labor as the

country's economic and social engine, thus carrying a propitious "discursive" potential.[11] In light of this representational relationship between architecture and the state, the closure of Cubiertas Ala appears as an inevitable endgame once the effects of development led to rising wood prices and increased minimum wages.[12] When costs rose and "cheap and handsome" was no longer viable, Cubiertas Ala simply went out of business.

Yet the physical and financial failures of the shells point toward a different formulation in the relationship of architecture and economy. This article looks at the intertwined story of the two collapses to suggest how—besides speaking of the state's ambitions—the shells afforded a mutually constitutive relationship between aesthetics and cost, one in which the economy functioned less as the driving force in the rise and fall of the shells than as the product of shell building. Indeed, in the course of the 1960s shell construction was an active site in the production of new practices of labor calculation that helped constitute the Mexican economy as a bureaucracy and, in the words of Timothy Mitchell, a "system of numerical knowledge." Within this emerging system, the shells yielded a new relationship between dynamics of labor and forms of "economic thinking" among the actors charged with their making.[13] Under this reading, the image of the shells still appears as part of their cost and system of production but in ways quite different from what was perceived at the time. The serendipitous pairing of "cheap" and "handsome" positioned aesthetics as an added value or bonus to the material efficiency of the shells. But the relationship of cost to image was considerably more intricate, a relationship where economic thinking was meant to take on a visual dimension. That is, the shells were not handsome in addition to being cheap; rather, they looked as they did in order to make visible their particular economy.

Inasmuch as an evolving system of economic thinking coalesced with the aesthetics and the making of the shells, they are better understood in terms of economic imaginaries. The shells suggest a dialectical relationship between two forms of economic imaginaries: *performed efficiency* and *embodied excess*. Within this dialectic, numbers quite different from those that populate the many studies of the shells come to the fore: the numbers of workers, aggregate, drawings, buckets, and contract prices, and not those of geometrical figures and structural soundness. In trying to make sense of these alternative numbers and the historical evidence they provide, this article retains calculation as a tool of architectural scholarship aimed not at structural reconstruction but as a means to reveal aspects of the work that went into shell building. Recalculating concrete thin-shells in this manner reveals the logic of

incalculability that buttressed the technology, image, and low price tag of the shells, and how they were eventually brought down by the emergence of a bureaucracy of calculability. These calculations draw from a range of sources—Candela's efficiency rationale, the visual narrative that sustained this thinking, the archive of the building process and the workers' experience on-site, and the shells as they stand—to speak of how these two imaginaries emerged and evolved in multiple ways between the construction site and the design studio, between the technologies of building and those of design, between Candela and his workers, and, perhaps most crucially, within the very materiality of the shells onto which these imaginaries were ultimately mapped.

By reconstructing the ways in which Candela and the workers of Cubiertas Ala sought efficiency at structural, financial, and aesthetic levels, the article chronicles how excess was in fact embodied in the shells, how costly they were, and how essential to their success it was to conceal behind the thinness of the concrete the enormous amount of bodies that went into their making. Cost and architecture came together precisely to realize this deceit—and herein lies the shells' primary magical quality: their ability to hide their economy of excess by displaying an economy of efficiency. And yet, despite the designer's best efforts, the marks and measures of excessive labor were not entirely abstracted in the shells or absent from their surfaces. As sites for the production of economic knowledge and, eventually, of a bureaucracy of calculability, the shells opened up a space for the workers to speak of their bodies as both tools for building and repositories of risk. This self-awareness, and the administrative apparatus that accompanied it, diverted the value of their labor from the symbolic to the financial—a transvaluation of values crucial to their becoming workers with legal rights.

Performed Efficiency: Building Knowledge while Edging the Shell

According to Candela, the Palmira Church was the project that best articulated the holistic approach to building technology and structural design he had advocated over the previous decade. Trained as an architect in his native Spain, Candela had arrived in Mexico as an exile from the Spanish Civil War in 1939, and a decade later began experimenting with thin-shell structures. After a few isolated trials with simple vaults, he founded Cubiertas Ala in 1950 with his brother Antonio as administrator, his sister Julia as secretary, and in association with the architect brothers Fernando and Raul Fernández Ragel. The tightly run family business designed, consulted on, and executed the construction of ever-taller and more complex thin

Félix Candela and Fernando Alvarez Ordoñez. Los Manantiales Restaurant, Xoichimilco, 1958. Exterior view. Courtesy Félix Candela Architectural Records and Papers Collection, Avery Drawings and Archives, Columbia University.

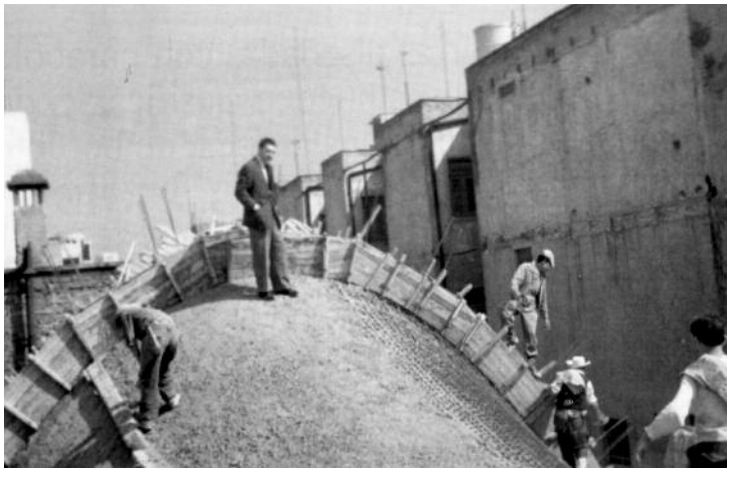
concrete shells in a business setting that was particularly apt for Candela. Unable to retrieve his architectural degree (he had graduated only weeks before the beginning of the Spanish Civil War in July 1936), Candela was never licensed as an architect in Mexico and was therefore unable to sign projects. Cubiertas Ala's buildings were always designed in collaboration with other architects, who dealt with all aspects of the design with the exception of the concrete. After completing the Cosmic Ray Pavilion—a vault little more than half an inch thick—for the Ciudad Universitaria in Mexico City in 1950, designed with Jorge González Reyna, Candela's reputation and Cubiertas Ala's commissions increased steadily.[14] From thirty commissions and eleven executed buildings in 1950, the company managed 130 commissions and forty-six built structures in 1957, its most prolific year, and continued at a range of twenty to thirty buildings per year for a decade after.[15]

The extensive production of shells came in tandem with Candela's evolving theories on building technology, a discourse whose political implications were long overshadowed by the perception, to a large extent self-promoted, of Candela as a nonintellectual technical expert.[16] A crucial concept in his theory was *construcción económica*, or affordable construction, which bolstered the cost efficiency of his architecture mostly in terms of material economization but also in "savings of time, savings of money, and savings of effort."[17] Candela saw this economic principle operating in his shells at two levels: the use of materials and the process of design and building. The most evident economization pertained to the minimization of building materials, which could be achieved by means of the geometry of the architectural form. The basis of Candela's architecture was his unrelenting exploration of ruled geometries, or shapes generated by the succession of straight lines that acquire static equilibrium by means of their form alone rather than by mass.[18] Candela's favored geometry was the hyperbolic paraboloid, or hypar, a saddle-shape form that subjects the surface to extremely low compression stress. This makes it ideal for concrete with little steel reinforcement and minimal thickness because of its structural capacity at compression. Moreover, the formwork (the supporting structure that holds and molds the liquid cement) can be constructed with straight wooden planks. The Palmira Church is a single hypar with an oblique cut in its larger opening to give the shell its dramatic height.

The rationale behind Candela's argument about cost efficiency was the modest expense of concrete, something he literally administered in his role as contractor with Cubiertas Ala. For each shell project, Cubiertas Ala signed a contract that included the structural design, the materials, and the execution of the concrete

section of the construction process—including all costs and decisions pertaining to labor.[19] According to the few contracts that remain in the company archives, Cubiertas Ala oversaw three main tasks, all concerning concrete: excavations and foundations, often including the floor slab; erecting the shell; and installing the insulation. The design of the foundation and the techniques for insulation were particularly delicate, as per Candela's own account, but the concrete shell was still the most expensive of the three items, amounting to 40–50 percent of the construction budget.[20] The numbers from contracts dating to the mid-1950s confirm the price of fifty cents per square foot that Candela marketed so proudly. (Early examples even show the company going as low as thirty cents per square foot.) This number, however, covered only the price of the shell. The remainder of Cubiertas Ala's work doubled the price and even then did not include the many other elements of the building as a whole. The contracted cost of each shell seems to have been an outcome of its geometry. The budget for the shell of the restaurant Los Manantiales, an eight-hypar circular structure erected in the winter of 1957–1958, was 384,000 pesos, or $30,000, while the three-hypar structure of the Church of San Vicente de Paul, built from December 1958 to August 1959, cost a little less at 324,000 pesos ($26,000). Although it was built twice, the single hypar of Palmira Church had an even lower price tag at 302,193 pesos ($24,000), while the earlier but more intricate Church de la Virgen de la Medalla Milagrosa, erected in 1953 in Mexico City, cost as much as 666,068 pesos ($53,000).[21] The more shapes a shell combined, the higher its price tag.

To these construction costs, Cubiertas Ala applied the customary 10 percent for fees.[22] Therefore, with inexpensive shells came limited income. For Candela, savings thus also had to operate at a second level, that of the intellectual and physical labor that went into the conception and building of the shells, which should be "relatively easy to undertake."[23] For the process of design, Candela famously relied on "intuition" and openly dismissed the production of complex mathematical calculations typically required for such structures.[24] Instead, he espoused an experimental approach whereby mathematical calculations were done mostly after construction, once the shells as built had served as proof of their viability. Juan Antonio Tonda, one of Cubiertas Ala's architects, later recalled the workings of the studio, where the math would be done with calculating tables until Cubiertas Ala purchased a few electric adding machines in the mid-1950s, followed in the early 1960s with punch card computers at the Ciudad Universitaria's computing center.



In each case, the mathematics of the shells involved substantial labor in the studio, which Candela continually sought to reduce, as he likewise did with the amount of drawing needed to define each shell.[25] Often, one plan and two elevations were sufficient to describe the full geometry and give enough information to erect the formwork and shell on-site.

For Candela, shell design took place not at desks and with calculation machines but on-site, where knowledge about the concrete and the hypars developed during the praxis of construction. This practice is thus similar to Pamela Smith's notion of an "artisanal epistemology" in early modern scientific practices, where material production and knowledge production occur in an integrated manner, mental and manual labor are unified, and expertise slowly grows among the collective engaged in manipulating the materials.[26] Cubiertas Ala employed a core group of master builders and workers often bound by family and regional ties, most of them country migrants from the same region who moved from project to project and from one building skill to another. Knowledge of the structural behavior of the forms, of the suitable mixtures for the aggregate, of the handling of the wooden planks, and of the construction process in general increased with each project, as each shell was in fact a prototype of the geometry and dimensions being tested. For Candela and his crew, every building offered a chance to raise the concrete higher, expand the shape, and "enclose" more space with less concrete. The aim was to take the design idea of the shell to its limit, gradually and for the purpose of ever more "savings."[27]

Such an empirical approach made it uncertain that the buildings would stand. The possibility of collapse was intrinsic to testing the limits of shell technology in this way, as well as to Candela's argument about efficiency. The prospect of failure, that is, was crucial to the piecemeal invention of the shell as a design system. In this process one element of the structure presented a particularly challenging burden: the edge beam, a steel-rod-and-concrete reinforcement running along the border to stiffen the structure and increase its load-bearing capacity. While the edge beam ensured the shell's structural performance, Candela felt it detracted from the ideal image of the shell. For he not only aimed at making the shells thin and ever larger for purposes of cost efficiency; he also hoped they would look the part. Refining the edge beam—and potentially disposing of it altogether—was essential to making the shells' efficiency apparent, since the edge beam hid the thinness of the shell when viewed from the outside. A 1955 construction photograph of the stock market in Mexico City shows Candela standing on top of the shell and right next to the edge beam as it is being cast. Per his later account, this was the moment he "discovered"

Félix Candela with Enrique de la Mora. Stock Exchange, Mexico City, 1955. Under construction. Courtesy Félix Candela Papers, Manuscripts Division, Department of Rare Books and Special Collections, Princeton University Library.

how to build free-edge hypars, which he first probed in the Church of San Antonio de las Huertas in 1956, a four-hypar building. Even there, though, the thinness of the concrete was not entirely perceptible from the outside due to the masonry walls that reached the border of the shell.[28] Candela subsequently developed the free-edge solution to remarkable results in the Los Manantiales restaurant in Xochimilco, south of the historic center of Mexico City. Standing thirty-three feet at its highest point, the lightness, thinness, and continuity of this shell was wittingly emphasized by a recessed footing and glass vertical enclosure.

When construction of Los Manantiales began in December 1957, Cubiertas Ala had already received the commission for an open church in Cuernavaca, to be designed alongside architects Guillermo Rosell and Manuel Larrosa. The work in Manantiales lasted until March, during which time Candela began to conceive of an even taller free-edge shell. In February, he signed a drawing for a fifty-nine-foot-high hypar for Palmira. After completing the restaurant in Xochimilco—and presumably gaining confidence in the free-border solution developed there—the Palmira shell rose to seventy-nine feet in a design signed in June 1958. This taller version shows reinforcement beams along three axes, one running through the spine and two parallel to the mouth but recessed toward the inside so as not to be visible. Further testing the resistance of the shell, the drawing incorporates a rose-window-like engraving on the top of the shell, as per Rosell's design, which additionally thins the concrete toward the top.[29]

While under construction, this shell collapsed. In response, and as per one drawing of the final design dated February 1959, the engraving disappeared, and the structure was lowered ten feet. Additionally, a reinforcement beam of sorts returned to the edge of the shell, but it was built upward in a way that visually emphasized the lift of the shell. In their mathematical analysis of the various designs, David Billington and Maria Moreyra Garlock prove the structural feasibility of the tallest and ultimately failed version, determining that the collapse was the result not of too much risk in the design but of flawed execution. Candela's resistance to calculations in the office, however, denied him the chance to understand the numerical feasibility of the tallest shell. The epistemology of the shells was in fact not mathematical but artisanal. The simplest, most efficient course was to build the shell again, slightly adjusting the design to ensure success.

The episode underscores how Candela relied entirely on the site as testing ground, the space where he empirically demonstrated how the shell—as built—took the geometry, the material, and the construction process to its limit. The collapse also

Félix Candela with Guillermo Rosell and Manuel Larrosa. Open Palmira Church, Cuernavaca, Mexico, 1959. Photograph by Armando Salas Portugal. Fondo Armando Salas Portugal.

points to the site as the primary repository of the risk that sustained the invention of shell technology, a risk that was localized, more pressingly, to a specific group of people: the workers. Candela understood this well, and found ways to justify this uneven distribution of risk through an idealized conception of craft technology and humanism. Rejecting the calculating machine in favor of manual labor, Candela decried "the total mechanization of the labor of design or invention [which] implied the elimination of man, considered a disturbing and unpredictable element."[30] In Candela's staunch apologia for intuition over calculation, experience over numbers, and craft techniques over mechanization, he conceived of technology alongside a "new humanist" narrative and specifically targeted contemporary trends of technological determinism and mechanical rationalism. A reader of philosopher José Ortega y Gasset, who condemned the dehumanization of modern art and mounted a similar argument with regard to technology, Candela rejected mechanization in the design process and industrialization in construction.[31] His evolving theory of building technology went beyond a mere utilitarian view of the conditions within which he operated; it involved a fully fledged vision for an alternative modernity. Candela considered structural design and building practices not only as the material basis for his shells but as providing for a new socioeconomic and cultural paradigm of progress. In Candela's vision, progress would be driven by an "intermediate technology" (rather than high tech), by an economy of efficiency (rather than capitalist consumption), by an artisanal epistemology (rather than mathematical), and by informal (rather than managerial) modes of production.

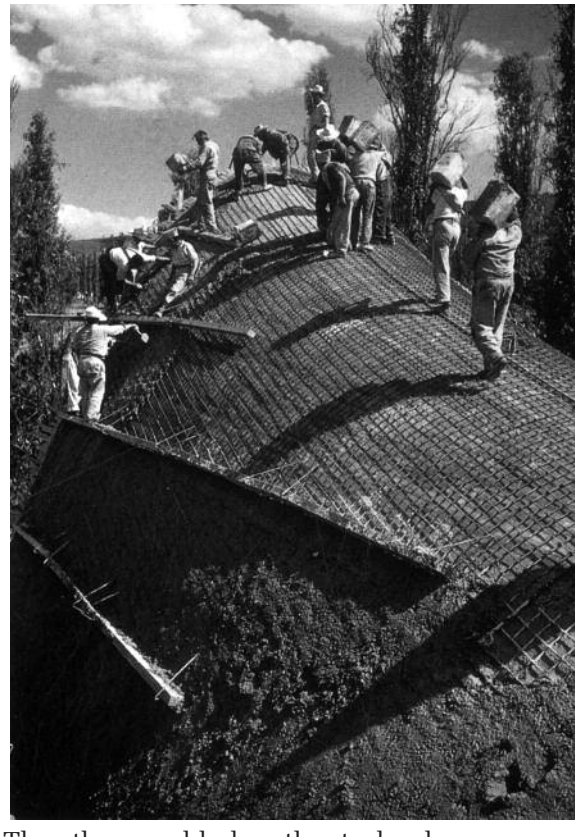
Within this vision, the shells as built operated for Candela as primitive huts of sorts, building models whereby geometric form, structural form, and architectonic form not only cohered under a holistic vision of humankind, nature, and the built environment but were the seed of an emergent model of culture. The image of the finished building was meant, for Candela, to carry this cultural paradigm, whereby the ideal of efficiency was anchored in the visual impact of the shells as much as in the engineering and the economics of concrete construction. That is, for Candela, material and design efficiency were tantamount to making efficiency visual. This

was also the ambition of the photographs of the Palmira Church shot by photographer Armando Salas Portugal right after completion. Taken for promotional purposes, they were published profusely in the media, as well as in Candela's monograph of the period, to present the building in terms of the most ideal of modernist paradigms.[32] Shot from below at oblique angles, the pictures of the uninhabited building portray the shell as a weightless, abstract, thin surface seemingly about to take off.

Embodied Excess: Body Measures, Risk Records, and Labor Marks

A different set of images throws Candela's imagined efficiency into sharper focus: the many, many construction photographs Cubiertas Ala archived as witnesses to the process that was so crucial in producing knowledge about shell building. The most striking of the photographs were shot, also for publication purposes, by the same professional photographers. Perhaps most remarkable are those shot by Juan Guzmán at Los Manantiales, who also documented the completed buildings with similarly lofty aspirations. But in the construction photographs, rather than the efficient beauty of the finished buildings, one sees excess: an excess of bodies, an excess of work, an excess of workers. Their heads protected from the sun and the rain by straw hats and plastic bags, the workers are shown mixing the *revoltura* (aggregate), the liquid compound of cement, water, sand, and gravel that, once poured and set, turns into concrete; they are shown laying steel rods by hand and troweling the cement while balancing on their feet; they are shown pouring buckets, one at a time; and they are shown carrying those buckets full of *revoltura* up the structures and empty buckets down. Many pictures of the scaffolding and formwork show the excessive deployment of wood that was necessary to construct the shells. These images are typically less populated than those recording the laying of the concrete, but they equally foreground the monumental quantity of labor that went into their making.[33]

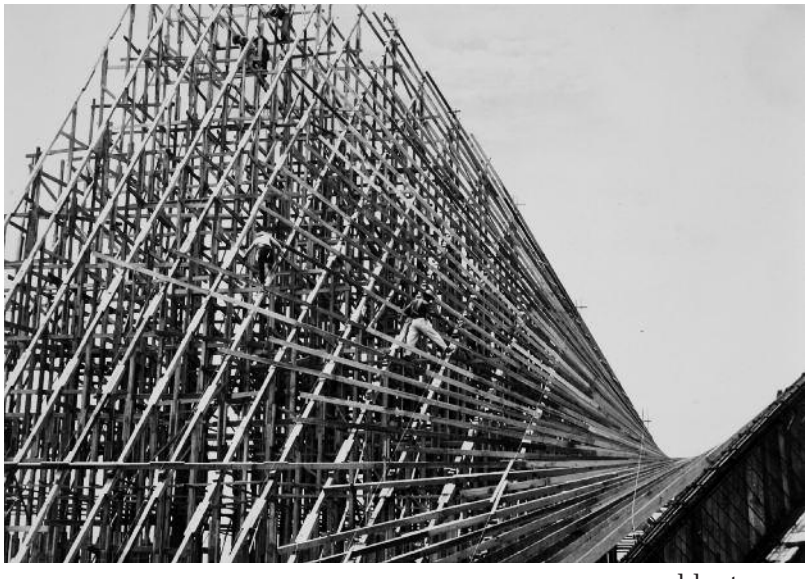
Nothing like the lyrical portrayal of the finished thin-shells, the construction photographs more accurately document the shells' economy of production. For as little concrete as was needed to build a shell, and as few drawings and calculations the process required, shell building mobilized enormous numbers of workers. That is, these photographs document the shells less as performers of an economy of means than as embodiments of the excesses in their system of fabrication. As in the geometric and structural analyses that have long occupied experts and admirers of concrete thin-shells, the construction images call for close calculation as a way to



Félix Candela and Fernando Alvarez Ordoñez. Los Manantiales restaurant, Xochimilco, Mexico City, 1958. Under construction. Photograph by Juán Guzmán. Manuel Toussaint Photographic Archive, Institute of Aesthetic Research, UNAM.

better understand this architecture. Only, the numbers here stand for the amount of work: the number of buckets, nails, wood planks, and, more pressingly, the number of bodies, hands, and feet that were ultimately the shells' most crucial technology.[34] Consider the physical routine on-site. After the complex woodwork for the scaffolding and form was complete, workers would grease the wood before laying a first *lechada* (layer) of *revoltura* of about three-quarters of an inch. Then they would place the steel rods for reinforcement before adding and troweling a second three-quarter-inch layer of *revoltura*. All of this was done by hand, with the *revoltura* shouldered in buckets as the workers climbed up the shell. The climbing mechanisms, devised ad hoc with pieces of wood, were often anchored to the formwork at the conjuncture of the hypars where the shell was the strongest. When the surface was too steep, as in the upper sections of the Palmira Church, workers would dangle from cables. The Palmira shell consists of approximately 16,000 square feet of curved surface and is one-and-a-half inches thick, thus requiring around 160 tons of *revoltura*. If each of the buckets held twenty liters (forty-four pounds) of *revoltura*, then the Palmira Church required around 7,270 buckets—each time it was erected. In all, to build the shell, workers walked up the temporary stairs or climbed up the cables 14,500 times carrying a full bucket of fluid cement, and as many times down.

In aestheticizing these routines, Guzman's visual narrative reveals how the glorification of manual labor sustained Mexican development at the time and how this very glorification bolstered labor exploitation. Candela's theories worked in a similar manner. For as much as both celebrated the workers and their labor, the worker as a distinct subject remained hidden: in the construction pictures, their faces behind the hats and in Candela's writings, their risk behind the economic imaginary of efficiency and the rhetoric of "humanism." Cubiertas Ala employed hundreds of workers on any given day, and yet not once in his lectures or letters did Candela describe the extraordinary number of workers required for shell building. However, despite his disregard for the quantification of physical labor, Candela did not entirely ignore the bodies that populated the shells' sites. In ways similar to Guzman's symbolic constructs, Candela folded these men into his narrative by way of the rhetoric of "new humanism" that was pervasive in architectural culture dur-

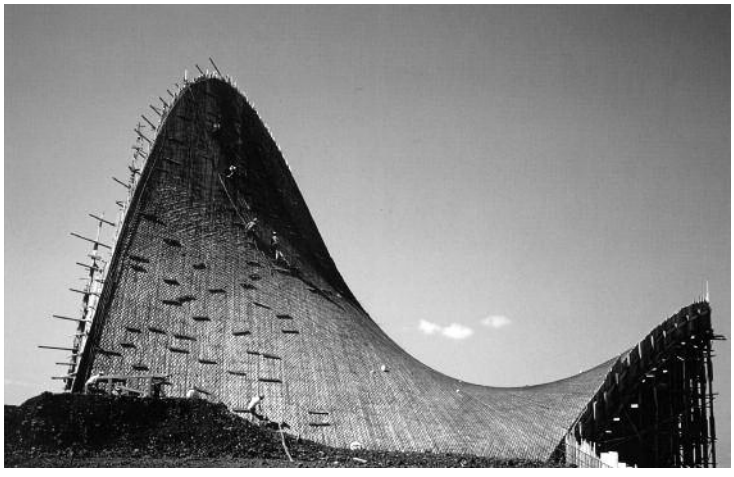


Top: Félix Candela with Guillermo Rosell and Manuel Larrosa. Open Palmira Church, Cuernavaca, Mexico, 1959. Wood formwork under construction. Courtesy Félix Candela Architectural Records and Papers, Avery Drawings and Archives Collection, Columbia University Libraries.

Bottom: Félix Candela with Enrique de la Mora. Stock Exchange, Mexico City, 1955. Under construction. Courtesy Félix Candela Architectural Records and Papers, Avery Drawings and Archives Collection, Columbia University Libraries.

ing the postwar period among those rejecting, or unable to work under, conditions of industrialized construction. For Candela, shell building advanced an ethics of production that "does not exclude man but instead facilitates simple instruments that lighten his labor, without eliminating him."[35] Just as he rejected the mechanization of his own labor as structural designer—via the calculating machine—Candela esteemed a building process that resisted industrialization and the objectification of workers via their calculability. Bodies were the shells' main technical device. Yet for Candela, bodies were better left unmeasured.

Whether intentional or not, the resistance to calculating the work and the bodies that went into shell building, specifically the hands that troweled and the feet that balanced, was far from inconsequential. That resistance was actually a means to reify the shells' conditions of possibility. For the shells proved viable only as long as the physical work on-site remained unaccounted for in economic and legal terms—or, just the same, as long as the construction site was populated by working bodies and not by workers as such. Since the late-nineteenth century, organized labor had been crucial to Mexico's political modernization, as the idea of the modern nation developed through a string of social revolutions nourished by the mass support of rural and urban workers. This Mexican model of social politics was, however, founded on a paradox, as historian Kevin Middlebrook argues, whereby labor was mobilized symbolically while workers' civil and economic rights were deferred so the state could sustain its grip over society and the economy.[36] Artists played no small role in providing the visual buttressing to maintain



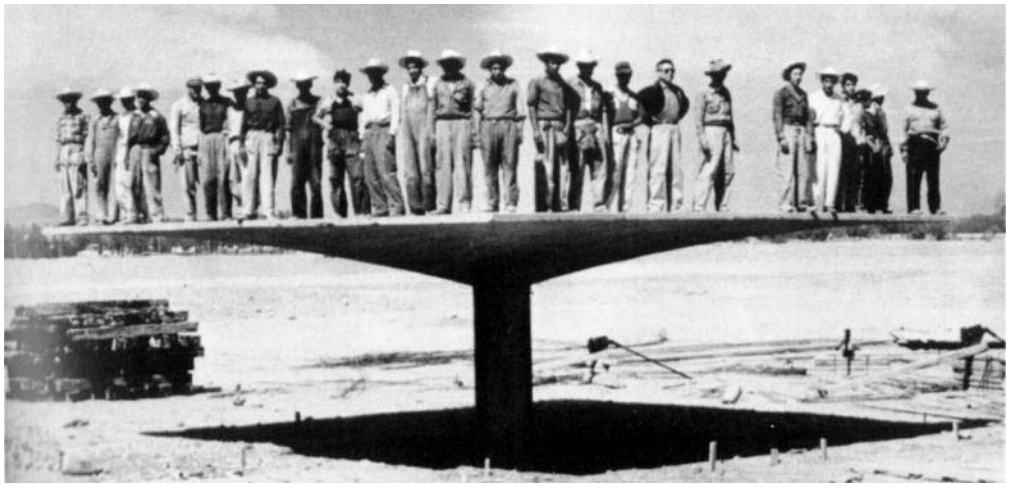
Left: Félix Candela with Guillermo Rosell and Manuel Larrosa. Open Palmira Church, Cuernavaca, Mexico, 1959. Shell under construction, 1958. Courtesy Félix Candela Papers, Manuscripts Division, Department of Rare Books and Special Collections, Princeton University Library.

Opposite: Félix Candela with Carlos Recamier. Experimental umbrella, 1954. Workers after decentering the structure. Photograph by Carlos Recamier. Courtesy Félix Candela Papers, Manuscripts Division, Department of Rare Books and Special Collections, Princeton University Library.

this paradox by elevating the Mexican worker, along with his straw hat and overalls, into symbols of Mexican modernity, most famously in Diego Rivera's murals and Tina Modotti's photographs.[37]

Both Candela's discourse on a humanist technology and Guzman's heroic representation of shell workers followed from this tradition, albeit at a significant conjuncture in the history of labor rights. In the 1940s, union leverage over worker's wages and living conditions was particularly weak, resulting mainly from the state's ambitious industrialization and infrastructure plans. While some workers retained leverage and influential unions, the building industry was particularly overlooked even though by 1950 construction provided half of the national net assets and was central to the growth of Mexico's economy.[38] A determining factor for the vulnerable conditions of the building industry was the excess of workers. As a 1972 report from the Organisation for Economic Co-operation and Development states, the preceding decade had witnessed a "supply of labor [that] has appeared to be almost unlimited." That is, a crucial factor of the exploitation of labor was its immeasurability. The worker in most abundance, paid the least, and most likely not to unionize was the *peón*, often rural migrants untrained for industrial work, who ranked lowest in skills and education.[39]

The *peón* is also who populates the shell construction photographs. In 1954, as per Cubiertas Ala's contract for the factory RIVETEX, the company ranked its workers on two skill levels: the *peón*, paid 9.60 pesos (70 cents) a day; and the *oficial albañil* or *oficial carpintero* (master bricklayer or master carpenter), paid double that rate.[40] The archives contain no records of the number of workers Cubiertas Ala employed in the mid-1950s or which task each performed, though clearly it is the low-wage *peón* who appears in the pictures carrying buckets up and down the shells. What sustained the construction site and the shell's logic of incalculability was the unlimited supply of *peóns*, their work similarly left unmeasured. Since the turn of the twentieth century in the United States and Central Europe, scientific management had informed working methods in concrete construction. The precise calculation and organization, in time and space, of building tasks and skills yielded a burgeoning economic system: capitalism. In these contexts, as Michael Osman argues, concrete architecture produced a deception characteristic of capitalist production, whereby a unified image hid the fragmentation of its working methods.[41] Midcentury Mexico tells a different story, however, both about the development of a national economy and about concrete's suitability for illusory effects. For what Candela's shells hid behind the unified and poetic image of efficiency was the

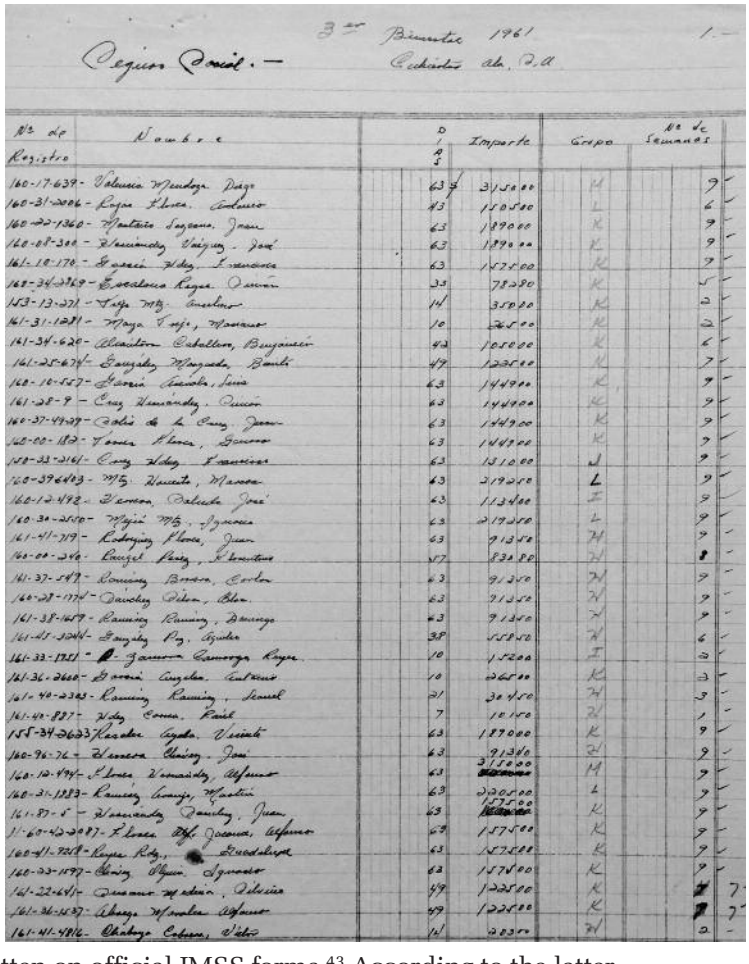


incommensurable and informal conditions of their production.

While performing this deceit, however, shell building also opened a space for the reconfiguration of the practice of calculation itself, a reconfiguration where the object of calculation shifted from the structure toward the bodies that erected it and their worth. This process was part of the reinvention of the economy in terms of a new politics of calculation that made "quantities and performances measurable, and designate[d] relations of control and command."[42] Perhaps more critical, the shells also allowed for the legal and economic reconfiguration of those populating the construction site—the worker who gained legal status and labor rights—and a bureaucratic apparatus that valued his hands and feet. That is, alongside an architectural knowledge about casting thinner shells, what developed on the site was an economic logic of embodied excess. Workers were never oblivious to the excessive and symbolic value of their labor, perhaps best seen in the few construction photographs of the crew right after decentering the structure. Standing on top of the shell as a way to prove the shell's stability, the men form an orderly line and, for once, look directly at the camera from above. The camera lens captures a moment of pride: the shell stands, and with it both the ideal of efficiency and the excess of human labor that it required is legitimized. At this point, architecture provided the worker mainly with emotional value, which perhaps served to redeem shell building, for its actors at least, from a dependence on the exploitation of labor that the illusion of efficiency so unapologetically sustained.

The deceit would be short-lived and partially undone from within. Vessels of a heroic and cheap Mexican workforce, the shells also bore the shifts in labor rights that saw the worker transition from a symbolic force to a legal one and ultimately made shell architecture obsolete. Following a series of strikes by education and railway workers in the early 1950s, the following decade witnessed an escalation in concern over labor rights and minimum wages. The nature of the photographs taken by Guzmán at Los Manantiales in the winter of 1957–1958 speaks to the urgency of labor issues at the time, when Secretary of Labor Adolfo López Mateos was elected president and began to implement new welfare policies. On December 30, 1959, the Mexican legislature passed Articulo 123-B, meant to strengthen the Instituto Mexicano de la Seguridad Social (IMSS) by mandating registration of workers and establishing a social security payment to be covered by the worker, the employer, and the state, the "Cuotas de Obreros Patronales."

This is precisely the moment when the worker took on a certain specificity and a quantifiable form at Cubiertas Ala. Starting in 1960, the company began to track



its workers and the labor that went into shell building. The resulting administrative documentation included long, handwritten lists produced every two months of workers with their full names, days and weeks worked, skill group, and money paid; social security identification cards; payment forms to cover the Cuotas de Obreros Patronales; and weekly summaries of numbers of workers, listed by skill and typewritten on official IMSS forms.[43] According to the latter documents, Cubiertas Ala employed between three and six hundred workers at any given time. Numbers varied substantially depending on the number of active building sites and the company possibly registered only part of its workforce, or did so with discrepancies regarding their skill and wage level, something the legal department of the IMMS audited with some regularity.[44] Still, as a whole, these registration documents evince diligent office work, precisely the type of work expense Candela was so eager to minimize. They more insistently reveal the excess that was at stake and the institutional apparatus that began to give numerical and legal form to the Mexican workforce.

The process was one not only of quantification of workers but, critically, of qualification or valuation of the workers' bodies. The Formas de Riesgos Profesionales (Labor Risk Forms) are the only archival trail (other than the construction photographs) of everyday life on the site. Mediated by the disenchanted paper of bureaucratic transactions and not the camera lens, these documents paint less heroic images. According to one of them, at around noon on November 16, 1966, Joaquin Adam Barrales, a twenty-six-year-old *peón*, was in the midst of decentering a section of a hypar "when a wooden beam of a weight of over 110 pounds" fell on his left wrist. After receiving first aid on site, he went to Cubiertas Ala's main office to report the accident, his second one in the five months he had been with the company. Afterward, the form reports, Barrales followed protocol by visiting an official IMSS physician, who recommended further medical treatment and granted

Cubiertas Ala. List of workers with headings for registration number, name, salary, skill group, and number of weeks worked, September–October 1960. Courtesy Archivos Cubiertas Ala, Archivos de Arquitectos Mexicanos, Facultad de Arquitectura, Universidad Nacional Autónoma de México.

Joaquin a seven-day leave from work. Three days later, Victor Rivero Lazaro, twenty and also a *peón*, reported he had been "walking down a stair with a bucket full of *revoltura*" when he stumbled and fell off the shell, which left him "hanging down from the left leg." His leave was of six days. José Bautista Romero, forty-four and an *albañil* (bricklayer), claimed to have squashed a finger on his left hand and was off for seven days. On November 21, Avelino Carrera Trujillo, a twenty-three-year-old *peón*, stepped on a four-inch nail with his left foot and was given a three-day leave.[45]

Typewritten in the office, possibly by the secretary of Cubiertas Ala, Julia Candela (Félix's sister), the forms surely paraphrase the workers as they describe the accidents in colloquial language. Each form locates risk on the worker's body while allowing him to conceive of and speak, in the archive at least, of its value. Collectively, the documents chronicle Cubiertas Ala's mounting risk-taking and related debt. In the six months preceding Avelino's accident, nine other workers stepped on nails, while others suffered nail-related injuries to their hands and feet or were injured after falling on the "muddy" site. In all, the company processed twenty Labor Risk Forms from June 16 to November 21, 1966, the only period for which such records remain in the archives. Additionally, IMSS filed debt claims against Cubiertas Ala to cover, retroactively, the medical expenses incurred by those accidents where, following article 48 of the social security law, labor risks "proved to have been produced intentionally by the patron." On May 4, 1967, for instance, the company's accounts were debited 295.20 pesos ($24) to reimburse the costs incurred by an accident that Juan Cervantes Martínez had suffered five years earlier.[46] None of the tracked accidents seem particularly dramatic, and they likely correspond to the day-to-day experience on sites with unregulated working conditions and informal construction processes. The overall cost of these accidents to Cubiertas Ala as leaves and IMSS claims piled up is unknown. Also unknown is what more-serious injuries resulted from major events—such as the collapse of a shell. No major injuries were reported after the fall of the Palmira Church in 1958. Whether this was indeed the case, however, or was just how the architects chose to recall it, the point is that the bodies that populated the site in 1958 were not yet legal workers, still not entitled to claim the harm to their bodies—much less to place a value on the hands and feet that were the shells' primary operating tools.

Scant as it is, the paper trail of the construction process records the excess of bodies that sustained Candela's imaginary of efficiency, as well as how this abundance was measured and took on legal form over the years as the union-state alliance slowly improved labor rights in Mexico. In addition to invigorating the IMSS, in 1960

Félix Candela with Guillermo Rosell and Manuel Larrosa. Open Palmira Church, Cuernavaca, Mexico, 1959. Photograph of interior surface by the author, September 2016.

López Mateos established minimum daily wages for government employees, and his successor Gustavo Diaz Ordaz extended the minimum wage to all nongovernmental workers in 1964. Cubiertas Ala took on some public commissions and regularly adjusted its wages to the legal minimum, expanding its categorization of skills from two to six ranks in the 1960s, the largest category still being the lowest one, the *peón*. From 1954 to 1960, the daily wage of the *peón* in Cubiertas Ala rose from 9.6 to 14 pesos (from 70 cents to $1.12), increasing to 21.50 ($1.72) by the summer of 1964 to match the legal minimum daily wage in Mexico City. By 1973, this number had doubled to 41.43 pesos ($3.30).[47] Ten times higher than when the company started building in 1950, minimum wages threw the cost efficiency of Candela's shells out of balance and proved to be a variable difficult to adjust to. Still, as was manifest in the financial collapse of Cubiertas Ala in 1973, what the company failed to cover was its dues to the IMSS. Presumably, Cubiertas Ala had by then acquired debt on more than one front, but it was the social security and labor risk payments that were first in the bankruptcy list. And so the story ends, with worker's rights over their bodies being paid for by the calculating machine that Candela's incalculable and intuitive work was meant to bypass.

For all of its lyricism, the Palmira shell thus gave form to the uneven economies and labor exploitation that define developmentalism at its core, an inequality whose effects were airbrushed with the felicitous pairing of "cheap and handsome." Heroic in the photographs and belated in the documentary archives of the shells, the worker was necessarily suppressed in the "mantra of efficiency" that the designer envisioned and most likely believed to be true.[48] Candela's suppression of this dynamic was propitious and hardly exceptional. Midcentury concrete thin-shells form but a sliver of a longer history in which spectacular architecture thrives on the exploitation of economic opportunities—be these of inexpensive material, inexpensive technologies, or, more often, cheap labor and the apparent obliviousness of the designers. For Candela, as for many others, exploitation was suppressed under pretenses of expertise in form-making and the symbolic and financial value of the finished forms, which both evinced his arguments about cost efficiency and absolved him from accountability to the excess bodies and work that were at stake.[49] Whether this was a conscious suppression or not, it was a necessary one. For only by hiding an excess (of labor) behind an imaginary of efficiency (in materials and structure) could these shells remain viable. In the end, the concealment of the high labor cost of the architecture under a pretense of "cheap and handsome" was a particularly sophisticated reification of capitalist abstraction—a system designed to

hide the social processes of production under the abstraction that is money.

The shells themselves, their refined abstraction notwithstanding, are where one can trace the workers' ghostly presence. For their surfaces hold the clues of the dynamics of labor and bodily technologies that provided the architecture with its surplus value. Workers marked the shells in at least three distinct ways. One pertains to the precise dimensions of the shells. As demonstrated in the construction of the Palmira Church, the specifics of the form were tested and determined on-site and by the workers. That is, the hypar was determined as much by the contextual conditions and the limits of construction as by the universal laws of geometry. The second signifier, a literal imprint of labor can be found on the inside surface of the concrete, where traces of manual labor remain on the bare surface. There one reads the exact size and disposition of the wooden planks of the formwork and feels their materiality through a textural effect that grounds the shell within the work of nailing the wood and pouring the *revoltura*. Finally, workers left tangible marks of the arduousness of their labor on the outside of the shells, specifically via the imperfections to the surface where one can still locate the wooden ladders they used to travel up and down the shell carrying buckets of cement, or the steel anchors around the edge on the Palmira Chapel from which they hung.

These markers of the making process interrupt the ideals of efficiency and abstraction that the shells were meant to project in their "straightforward" geometric construction. The image of the shells as thin, effective, structurally honest, and, above all, aesthetically spectacular was essential to securing their aura of mystery and went in tandem with the immeasurability of the labor. Built twice at the close

of 1958, the Palmira Church took full advantage of this illusion; that is, of the ways workers were placed at the center of industrial modernization only as a heroic force and at the expense of holding back their specificity and legal rights. The uplifting shell of the Palmira Church provided a strategic imaginary of Mexican modernity, working much in the manner of the fetish—and not only because, as a church, the building aimed to objectify godly powers. With what Karl Marx characterizes as the "metaphysical subtleties and theological niceties" of commodity fetishism, the soaring white thin-shell aimed to conceal the social character of labor that underpinned its production.[50] The magic was ultimately revealed from within. In time, the shells also allowed for a new logic of calculability to take hold, an economy that transferred value from the symbolism of the architectural object to workers, and a governing apparatus that identified their bodies as ultimate repository of the risk that invented the shell system. Architectural value, that is, was gradually transposed from the structural stability and aesthetic potential of the shells to the agency of the hands and feet that built them up—a dislocation that ultimately anchored the shells' rise and fall.

Félix Candela with Guillermo Rosell and Manuel Larrosa. Open Palmira Church, Cuernavaca, Mexico, 1959. Photograph of climbing mechanism on edge beam by the author, September 2016.

Notes

Thank you to Roy Kozlovsky, Lutz Robbers, Adrian Forty, Claire Zimmerman, Anooradha Siddiqui, Reinhold Martin, Patricio del Real, Cristina Lopez Uribe, Hugo Fernández Quezada, and the *Grey Room* reviewers for their helpful comments to previous versions of this article, which has benefited from the financial and intellectual support of the Society of Fellows in the Humanities at Columbia University and the School of Architecture of The Cooper Union. I owe the reflection on bucket numbers that frame the article to Dino del Cueto, whom I specially thank for our many conversations on the construction process of the shells and for his generosity in making Candela's oeuvre known and accessible.

1. Manuel Larrosa, architect of the Palmira Church, in conversation with Alfonso Basterra, quoted in "Félix Candela y el borde libre: El caso de la iglesia de Palmira en Cuernavaca," *Bítacora Arquitectura*, no. 5 (August 2001): 71. Basterra provides a detailed structural analysis of the Palmira Church and its collapse. Unless otherwise noted, all translations are by the author.

2. "Félix Candela: Architect of Shells," *Time*, 8 September 1958, 80–81; and "Wizard of the Shells," *Architectural Forum* 3, no. 5 (1959): 154–159.

3. "Actas de embargo" (1973), in folder 8.10, Archivos Cubiertas Ala, Archivos de Arquitectos Mexicanos, Facultad de Arquitectura, Universidad Nacional Autónoma de México (ACA AAM UNAM). Dollar amounts are given at the exchange rate of 1 dollar to 12.5 pesos; this rate followed the devaluation of the peso in April 1954 and lasted until 1976.

4. Candela was also involved in the design of the metro stations San Lázaro, Candelaria, and La Merced in Mexico City, inaugurated in 1969. By then, he had already parted ways with Cubiertas Ala, which continued business under Antonio and Julia Candela. For Candela's presence in the United States, see Angela Giral, "Candela en los Estados Unidos," *Bítacora Arquitectura*, no. 23 (November 2011): 48–57.

5. For a recent argument on obsolescence as a concept that foregrounds the economic in studies of architecture, because it pushes considerations of "measurable performance and quantifiable value" into the built environment, see Daniel Abramson, *Obsolescence: An Architectural History* (Chicago: University of Chicago Press, 2016), 6. My argument resonates with Abramson's inasmuch as I chronicle the emergence of the calculation of labor and wages in the Mexican building industry and measure the labor that went into shell building. Midcentury concrete shells, however, dislocate Abramson's argument (1) geographically, as shell economy does not entirely fit a Western version of capitalism; and (2) conceptually, insofar as the shells became obsolete as a technology or way of building that calls attention to relations of production and labor, and not as building-objects to be physically dismantled.

6. In *The Ten Books of Architecture* Vitruvius accounts for the role of design and financial failures in the building industry. Seminal to the study of concrete and failure are Jacob Feld, *Lessons from Failures of Concrete Structures* (American Concrete Institute, 1964); and Jacob Feld, *Construction Failure* (New York: John Wiley & Sons, 1968). For a broader literature review on the topic, see Henry Petroski, "The Success of Failure," *Technology and Culture*, 42, no. 2 (2001): 321–328.

7. Daryl Hafter, "The Cost of Inventiveness: Labor's Struggle with Management's Machine," *Technology and Culture* 44, no. 1 (2003): 102–113.

8. The shells are staples in the architectural histories of Latin American modernism, where they are invariably presented in terms of Candela's ingenious approach to structural design. Reyner Banham was an early reviewer of the structural and economic virtues of Candela's work in "Simplified Vaulting Practices," *Architectural Review* 114 (1953): 199–202. The literature on Candela and his life is extensive and almost invariably hagiographic. See especially Juan Ignacio del Cueto, ed., *Félix Candela 1920–2010* (Madrid: Sociedad Estatal de Conmemoraciones Culturales, 2010); Pepa Casinello, ed., *Félix Candela: Centenario 2010: La conquista de la esbeltez* (Madrid: Fundación Juanelo Torriano, 2010); and Enrique de Anda, *Félix Candela, 1910–1997: The Mastering of Boundaries* (Cologne: Taschen, 2008). Since the publication of the seminal monograph by Colin Faber, *Candela: The Shell Builder* (New York: Reinhold Publications, 1963), the most common interpretation of Candela's architectural practice pertains to a technical description of the shells. The most thorough is David Billington and Maria E. Moreyra Garlock, *Félix Candela: Engineer, Builder, Structural Artist* (New Haven, CT: Yale University Press, 2008). Recent and brief accounts of the role of Candela within Latin American modernism are Luis Carranza and Fernando Lara, eds., *Modern Architecture in Latin America: Art, Technology and Utopia* (Austin: University of Texas Press, 2015), 184–185; and Louis Noelle, "Mexico," in Barry Bergdoll et al., *Latin America in Construction: Architecture 1955–1980* (New York: Museum of Modern Art, 2015), 218–219. A review of Candela's work in the context of midcentury Mexico is in Enrique de Anda, *Historia de la arquitectura Mexicana* (Barcelona: Gustavo Gili, 2013); and for a more critical account, see Luis Castañeda, *Spectacular Mexico: Design, Propaganda, and the 1968 Olympics* (Minneapolis: University of Minnesota Press, 2014).

9. "Félix Candela: Architect of Shells," 80.

10. Ruben Gallo, *Mexican Modernity: The Avant-Garde and the Technological Revolution* (Cambridge, MA: MIT Press, 2005), 185. Gallo's approach to the cultural dimension of cement is literary, and he posits "the magic of cement" as essential to understanding its cult value. An essential and multivalent account of the cultural dimension of concrete, one in which Mexico's thin-shells are, however, absent, is Adrian Forty, *Concrete and Culture: A Material History* (London: Reaktion Books, 2016).

11. Castañeda, 37–39, 139.

12. Castañeda, 279. Contemporaneous guides to Mexico evince a strategic pride over inexpensive labor and goods. See, for instance, Norman Ford, *Fabulous Mexico: Where Everything Costs Less!* (Greenlawn, NY: Harian Publications, 1966).

13. Timothy Mitchell, *Rule of Experts: Egypt, Techno-Politics, Modernity* (Berkeley and Los Angeles: University of California Press, 2002), 5, 93; and Timothy Mitchell, "Rethinking Economy," in Rethinking Economy, special issue, *Geoforum* 39, no. 3 (May 2008): 1116–1121. For an overview of development policies and economic thinking in Mexico at midcentury, see Elsa Gracida, *Historia económica de México: El desarrollismo* (Mexico D.F.: Oceano, 2004).

14. For more detail on Candela's biography, see Cueto, 21–120.

15. Fichas de proyectos y obras, in wooden box, n.d., ACA AAM UNAM.

16. María González Pendás, "Technics and Civilization: Félix Candela's Geopolitical Imaginary," in

Latin American Modern Architecture: Ambiguous Territories, ed. Patricio del Real and Helen Gyger (New York: Routledge, 2003), 271.

17. Félix Candela, "Arquitectura: Arte a extinguir," typewritten original, n.d., in box 05.09, Félix Candela Architectural Records and Papers, Avery Drawings and Archives Collection, Columbia University (FCA CU). See also Félix Candela, "Arquitectura y estructuralismo," *Arquitectura* 59 (1963): 23.

18. The technical description of shell architecture has been thoroughly elucidated in the scholarship; see n. 8 above.

19. On Cubiertas Ala's "freedom to administer labor," see Contrato Sandoval, September 1952, in clausula 2, folder 10.4, ACA AAM UNAM.

20. Folders 8.1 and 5.5, ACA AAM UNAM. To this day, the insulation remains the shells' Achilles' heel, affecting their life span and the most expensive item in their maintenance.

21. Fichas de proyectos y obras, n.d.

22. Contrato Maria de Christlebe, n.d., in folder 10.4, ACA AAM UNAM.

23. Candela, "Arquitectura y estructuralismo," 23. For a recent assessment of the various dimensions of labor in architecture, see Peggy Deamer, ed., *The Architect as Worker: Immaterial Labor, the Creative Class, and the Politics of Design* (New York: Bloomsbury Academics, 2015). In the introduction, Deamer calls for a more nuanced understanding of the work of design in architecture in terms of immaterial labor, as opposed to the material labor of construction work.

24. The intuition-over-calculation argument is commonplace in the coverage of Candela's work. See for instance, Betty Campbell, "Felix Candela," *Concrete Quarterly*, no. 42 (1959): 3–4.

25. Juan Antonio Tonda, "Cubiertas Ala," in *Félix Candela 1920–2010*, 245–250.

26. Pamela Smith, *The Body of the Artisan: Art and Experience in the Scientific Revolution* (Chicago: University of Chicago Press, 2004). In favoring the site and the process of construction, Candela was not alone in the history of architecture. A salient case from the period is the Brazilian Sergio Ferro, who in the 1960s articulated a critique of high modernism by calling for a critical Marxist reevaluation of labor in architectural design with an emphasis on construction processes derived from building with concrete. Sergio Ferro, *Arquitectura e trabalho livre* (São Paulo: Cosac Naify, 2006).

27. Félix Candela, "El cascarón como delimitador del espacio (1954)," in *En defensa del formalismo y otros escritos* (Madrid: Xarait Ediciones, 1985), 103. For a summary of Candela's evolving structural system, see Billington and Moreyra, 170–173.

28. Faber, 138. For a description of how this construction detail evolved throughout Candela's career, see Billington and Moreyra, 82–86; and Basterra.

29. Félix Candela for Cubiertas Ala, Iglesia de Cuernavaca, pencil and ink on tracing paper, June 1958, in Series I: Project Records, drawer 72, folders 5, 29, FCA CU.

30. Félix Candela, "Influencia de la tecnología en la creatividad arquitectónica," *Arquitectura* 303 (1995): 63.

31. As noted early on by Campbell, 2–6. Candela also drew from Lewis Mumford and Jacques Ellul for his theories on building technology. Candela, "Influencia de la tecnología," 65. Ortega y Gasset's writings on technology and architecture include "El mito del hombre allende la técnica," his

conference presentation for the 1951 Darmstadt Colloquium *Mensch und Raum* (Man and Space); and "En torno al Coloquio de Darmstadt," in *Meditaciones de la técnica y otros escritos sobre ciencia y filosofía* (Madrid: Alianza Editorial, 1982), 99–134.

32. Elisa Lozano, "Fragmentos: Candela, arquitectura, fotografía y cine," in *Félix Candela 1910–2010*, 211–240.

33. For an analysis of the prominent role of the formwork that also considers labor and the economics of architecture more generally, see Forty, 225–227.

34. The hand as a technology crucial to architecture has a long history. For a classic articulation, see John Ruskin's *The Seven Lamps of Architecture* (New York: John Wiley & Sons, 1885). For an argument about the relationship between workers' bodies, architecture, and media that also mobilizes the concept of calculability as crucial to understanding architecture within economic and other governing processes, see Lucia Allais, "Integrities: The Salvage of Abu Simbel," *Grey Room*, no. 50 (Winter 2013): 21–23. Historians of the early modern period have called attention to the hand as both a technology and a means of knowledge in Lissa L. Roberts, Simon Schaffer, and Peter Dear, eds., *The Mindful Hand: Inquiry and Invention from the Late Renaissance to Early Industrialisation* (Amsterdam: Edita, 2007).

35. Candela, "Influencia de la tecnología," 66.

36. Kevin Middlebrook, *The Paradox of Revolution: Labor, the State and Authoritarianism in Mexico* (Baltimore: Johns Hopkins University Press, 1995), 2–3.

37. John Lear, *Picturing the Proletariat: Artists and Labor in Revolutionary Mexico, 1908–1940* (Austin: University of Texas Press, 2017).

38. Dimitri Germidis, *Labour Conditions and Industrial Relations in the Building Industry in Mexico* (Paris: Organisation for Economic Co-operation and Development, 1974), 12. See also, Dan LaBotz, *The Crisis of Mexican Labor* (New York: Praeger, 1988).

39. Germidis, 13.

40. Contrato de "Rivetex s.a.," in folder 5.5, ACA AAM UNAM. On Cardenas's efforts in the realm of labor, see Nora Hamilton, *The Limits of State Autonomy: Post-revolutionary Mexico* (Princeton, NJ: Princeton University Press, 1982).

41. Michael Osman, "The Managerial Aesthetics of Concrete," *Perspecta* 45 (2012): 67–75; and Forty, 234–243.

42. Mitchell, 8.

43. Tarjetas administrativas; Lista bimestral de trabajadores; Resumen semanal de liquidación por grupos de salario; Pago de cuotas de obreros patronales, in folders 8.3–8.14, ACA AAM UNAM.

44. Ordenes de verificación, in folder 8.5, ACA AAM UNAM.

45. Riesgos profesionales, in folder 8.7, ACA UNA.

46. Ley de Seguro Social, Articulo 48, as stipulated by the Debt Services of the IMSS in a "Notificación" to Cubiertas Ala, 4 May 1967, in folder 8.10, ACA AAM UNAM. Only one document of this type remains in the archive. As with the Labor Risk Forms, it is likely that many more were filed.

47. Lista bimestral de trabajadores.

48. For an argument about the ways in which efficiency evolved from an eminently engineering

value to a social mantra, or a belief that underpinned social conceptions of modernity, see Jennifer Alexander, *The Mantra of Efficiency: From Waterwheel to Social Control* (Baltimore: Johns Hopkins University Press, 2008).

49. Joan Ockman, "Foreword," in *The Architect as Worker*, ed. Deamer, xxiii.

50. Karl Marx, *The Process of Capitalist Production*, vol. 1 of *Capital: A Critique of Political Economy* (London: Penguin Books, 1990), 163.