Beyond the National Art Schools: Thin-Tile Vaulting in Cuba after the Revolution

M. WESAM AL ASALI
University of Cambridge

DANIA GONZÁLEZ COURET
Universidad Tecnológica de La Habana (CUJAE)

MICHAEL H. RAMAGE
University of Cambridge

The Cuban Revolution in 1959 also marked a revolution for the history of architecture in Cuba. Led by Fidel Castro, the new Cuban government set about producing a new kind of architecture intended to improve social conditions for all of Cuban society, as attested by the mass production of housing and schools across the island. The methods employed to fulfill this promise were equally unprecedented. State-sponsored investigations into building techniques launched a period of lively experimentation aimed at industrializing both the production of local materials and traditional construction methods. The construction of thin-tile vaults, and ceramic vaults in general, played a central role in meeting the government’s objectives, and the study of these vaults offers insights into the design and construction of this new Cuban architecture. Other scholars have referred to a transitional period between the use of conventional construction methods and the introduction of industrialized techniques and prefabrication following the Cuban Revolution; in this investigation, we focus on the evidence of thin-tile vaults to explain how this transition took place.

From 1960 to 1965, Cuban architects and engineers conducted extensive experiments involving the materials, labor, and fabrication processes required to build thin-tile vaults. These experiments led to the building of numerous projects across Cuba both in spite of and in response to straitened economic circumstances caused by the imposition of international sanctions, massive societal upheaval caused by the nationalization of construction companies, and the exodus of leading architects associated with the previous regime of Fulgencio Batista. In this article we examine the use of thin-tile vaults in Cuba after the revolution as a bottom-up approach to construction that exploited and transformed traditional techniques for the purposes of large-scale, industrialized applications.

We first present a brief overview of vaulting in Cuba before and after the revolution before considering the case of the thin-tile vaults designed for the famous project of the Escuelas Nacionales de Arte, or National Art Schools. Drawing on newly available archival sources, we pay special attention to drawing and modeling as key methods that can be used to interrogate our archival and fieldwork findings. We then turn to a discussion of how and why early experiments on thin-tile vaults took place, and the subsequent consolidation and formalization of these activities with the creation of a state-supported research center. This in turn offers new insight into the construction of the thin-tile vaults at the National Art Schools. Projects using thin-tile vaults included both numerous houses and schools until 1965, when Cuba’s
changing construction policies led to the abandonment of thin-tile vaulting for state-supported construction projects.

The Adoption of Structural Shells in Cuba

Builders have employed thin-tile vaulting techniques for centuries. Thin-tile vaulting is both less labor-intensive and more economical to construct than more traditional masonry vaulting: by using flat tiles that are lighter than normal bricks and bonding them horizontally with a fast-setting mortar (rapid cement or plaster of Paris), a skilled mason can quickly build a thin-tile vault using only minimal formwork (temporary support during construction) and guidework (a light structure that provides a visual guide for the construction of the vault surface). Once the soffit of the vault is completed, it serves as a first layer on which subsequent tiles may be placed, bonded with normal cement or lime mortar. The addition of subsequent layers of tiles increases the overall thickness of the vault, and for this reason, thin-tile vaults are occasionally called laminated vaults.

In Spain, where the use of thin-tile vaulting is widespread (called bóveda tabicada, bóveda catalana, and sometimes bóveda extremeña), this traditional technique is often employed for stairs and ceilings. In the early twentieth century, Spanish architects drew upon this established vernacular tradition to create daring and expressive structures in the style known as Catalan modernisme; mid-twentieth century reconstruction projects following the Spanish Civil War (1936–39) also used the traditional technique.

While other European building traditions also incorporated thin-tile vaulting, the technique’s largest leap occurred when it traveled across the Atlantic to North and South America. Perhaps the most famous instance of this transfer was the work of the Valencian architect Rafael Guastavino (1842–1908), who arrived in New York in 1881 and started a successful company with his son Rafael Guastavino Jr. (1872–1950), building thin-tile vaults across North America.

Unlike in North America, where Guastavino’s patents limited any development of thin-tile vaulting outside his company, designers elsewhere experimented with the technique in their search for affordable construction solutions. Architects and structural designers in Central and South America faced with limited resources discovered that thin-tile vaulting roof systems were efficient and cost-effective for large-span warehouses, low-cost housing, and prefabricated structures. Their designs were significant not only in terms of their innovative architectural forms but also as examples of social and political responses to problems of scarcity. In Cuba, however, such experiments had to wait for the revolution, following which the state identified thin-tile vaults as a means to get around the problem of the absence of a Cuban steel industry, an ingenious architectural solution that adopted the local use of everyday materials and could be built at a wide range of scales.

Cuban architects had already pioneered modern vaulted projects before the revolution, as in the designs of Max Borges Jr. (1918–2009), including the Tropicana cabaret Sala de los Arcos de Cristal (1951), the flower shop Antilla (1955), and Nuñez Bank (1957). These shells have little in common with their postrevolution equivalents, however. In addition to featuring reinforced concrete rather than thin-tile vaults, the expressive forms of these earlier designs were sometimes linked to projects associated with Batista’s regime; the unbuilt Palacio de las Palmas, by Félix Candela (1910–97), Paul Lester Wiener (1895–1967), and Josep Lluís Sert (1902–83), is one example. But the fundamental difference between these sets of projects and the postrevolution thin-tile vaults was that the earlier designers were focused on individual buildings, as opposed to designing architectural systems in response to a national crisis in housing and education. Perhaps this distinction has been obscured for later audiences, given that the only internationally celebrated Cuban buildings with thin-tile vaults built after the revolution are the National Art Schools, which feature spectacular large-span vaults that are undeniably expressive and sculptural. As we will see, however, the commission for the art schools represented the exception rather than the rule in the postrevolutionary history of Cuban thin-tile vaulting.

Castro envisioned the National Art Schools as a means of revolutionizing art education in Cuba and at the same time creating a powerful and lasting national and universal symbol for the revolution itself (Figure 1). Begun in 1961, the project was led by the Cuban architect Ricardo Porro (1925–2014) in collaboration with two Italian expatriate architects, Roberto Gottardi (1927–2017) and Vittorio Garatti (b. 1927). Occupying the site of an elite former golf course in Cubanacan on the western edge of Havana, the National Art Schools consisted of five separate schools. Porro designed the School of Modern Dance and the School of Plastic Art, while Garatti designed the School of Music and the School of Ballet, and Gottardi designed the School of Dramatic Arts. Thin-tile vaulting represented a necessary alternative for these designers, given the scarcity of materials available for concrete construction.

And yet the striking use of ceramic bricks and curved shell vaults at the National Art Schools resulted in astonishing designs that seamlessly integrated these organic forms within the existing natural landscape.

Although begun with great enthusiasm, work at the National Art Schools halted in 1965. Only the schools by Porro were completed; the rest were abandoned. The unfinished buildings survived, although in deteriorating condition. In the 1980s the site gained renewed attention after Hurricane Alberto caused extensive flooding and damage in 1982. At the same time, a contemporary Cuban architectural movement...
known as the Generation of the 1980s helped to raise new interest in the complex by celebrating the National Art Schools in both texts and exhibitions.15

Scholarship on the National Art Schools argues that the project’s failure was tied not only to the government’s changing policies regarding construction but also to a lack of knowledge regarding thin-tile vaulting among the employees of the Cuban Ministry of Construction, or MICONS (as it is known in Cuba, and as we refer to it going forward), who were responsible for directing these projects.16 In particular, scholars assert that MICONS employees tended to regard these innovative construction techniques with mistrust and suspicion because of their unfamiliarity.17 However, as we will demonstrate, these assumptions are highly questionable. Not only did thin-tile vaulting exist in Cuba as a traditional construction method before the National Art Schools, but it is also clear that MICONS conducted systematic investigations into thin-tile vaulting between 1960 and 1965.18

MICONS’s support for thin-tile vault construction has been further obscured by accounts describing a mysterious Catalan (or Valencian) builder named Gumersindo, who built a demonstration thin-tile vault that convinced the MICONS architects to hire him to assist in the construction of this project.19 So far, no scholars have documented the thin-tile vault prototype built for MICONS or even investigated the need for such a prototype. Questions about Gumersindo’s contribution—whether he took part in a larger thin-tile vaulting initiative organized by MICONS, or if there were many more Gumersindos at MICONS—still need to be addressed. If recent scholarship has helped us to acquire a better understanding of the design of the National Art Schools, we still have much to learn about the process surrounding the development of their complex vaulted structures and geometries.

From Building Drawings to Drawing Buildings
In the remainder of this essay, we take a closer look at the operation of the state agency MICONS. Our investigation involves the close scrutiny of primary and secondary sources, including the publications issued by MICONS from 1959 to 1965, as well as interviews with architects and engineers who were assigned to examine the use of ceramics in construction during this period. In addition, we focus in particular on materials drawn from a rarely examined photographic archive in the Documentation Center (Centro de Documentación, Empresa RESTAURA) at the Office of the Historian of the City of Havana (Oficina del Historiador de La Ciudad de La Habana). The archive originally belonged to the Center of Technical Investigation at MICONS. Although much of the MICONS archive is either lost or inaccessible, Juan de las Cuevas Toraya obtained photos of research on thin-tile vaulting conducted at MICONS from 1961 to 1965 that he later provided to the photographic archive at the Documentation Center, which is dedicated to the documentation and restoration of the built environment of Havana and has no connection to MICONS. Not surprisingly, given that scholarship on Cuban thin-tile vaults has focused overwhelmingly on the intriguing aesthetic, cultural, structural, and political complexities of the National Art Schools, these materials have also rarely been consulted.20

Following our archival investigations, we conducted interviews and site visits to learn more about the complex and evolving architectural experiments during this unique moment in Cuba’s history; we then used drawings and digital models to interrogate our findings.21 To verify whether MICONS guidelines informed the designs of actual buildings, we superimposed the drawings and models on building photographs. Also, 3-D modeling enabled us to generate perspectives that were not always possible to view in photographs and to make new comparisons between different thin-tile vaults.

Our research revealed that thin-tile vaults were adopted throughout Cuba for diverse uses, including housing blocks, industrial structures, educational facilities, and recreational complexes. If less monumental than those used at the National Art Schools, these other vaults were still less significant for three key reasons. First, the history of thin-tile vaults in these lesser-known buildings helps us to understand the context of...
the construction of the vaults at the National Art Schools, as part of a broader phenomenon of ceramic thin-tile vaulting construction that occurred in the years after the Cuban Revolution. Second, the institutional use of thin-tile vaulting by MICONS invalidates the conventional assumption of a divide between the architects of the National Art Schools and their counterparts at MICONS. Instead of MICONS employees being wary of the technique of thin-tile vaulting per se, it is more likely that MICONS mistrusted the expressive formalist approach adopted by the architects of the National Art Schools. Finally, by examining the history of a state-led initiative to investigate thin-tile vaults, we can begin to provide a more nuanced account of the history of construction in Cuba after the revolution, and in particular the tensions that supposedly emerged during this period between traditional and prefabricated architecture.

**Experimental Thin-Tile Vaulting in El Patio del MICONS**

The 1959 revolution marked a pivotal moment in the history of architecture and construction in Cuba. With Castro’s victory came a drastic expansion of the scope of construction projects. The housing budget doubled in 1959–60, with the creation of many state-sponsored research agencies to promote housing construction in both rural and urban areas, as well as self-built housing. As the number of educational facilities doubled in Cuba after the revolution, teams took form at MICONS to produce the designs for these new schools. With these demands came a shift in how local materials and building knowledge were approached. The new emphasis on available resources reflected both economic limitations and the fulfillment of the revolution’s aim to establish bottom-up construction practices, translated into labor training, systematization of building processes, and integration of prefabrication with conventional building methods.

Eager to exploit native Cuban resources, architects soon turned to Camagüey, a central-eastern province with a long tradition of brick making. In March 1960, two collaborators from the ceramic investigation unit of MICONS, architect Juan Campos Almanza (1930–2007) and engineer Alfredo Pérez, constructed the first brick vault built in Cuba after the revolution (Figure 2). The site of this trial vault was the famous Azorín brick and ceramic factory near Camagüey. The design featured double vaults resembling birds’ wings, built with bricks on sliding formwork. Campos later adapted this solution for the design of beachfront houses (cabañas) in Santa Lucía, north of Camagüey, which was built in just forty days (Figure 3). Later in 1960, another trial vault construction project took place in Santiago de Cuba (see Figure 2).

In 1961, investigations into materials and construction across Cuba were consolidated within the newly founded Center of Technical Investigation (Dirección de Investigaciones Técnicas) in Havana, led by Hugo D’Acosta Calheiros (1932–2010). The center was placed under the direct supervision of MICONS and was located in a two-story office building directly behind the ministry’s building in the Plaza de la Revolución. Construction of the building that would house the new research center began in December of the previous year; it featured concrete block vaults on its upper floor (Figure 4). Subsequent construction trials and experiments took place in the open space between the ministry building and the new research center, a courtyard that would come to be known as El Patio del MICONS until its relocation to east Havana in 1965. The Center of Technical Investigation focused on the systematic study of ceramics used for structural elements, as summarized in two reports: Cerámica convencional, which was devoted to unreinforced vaults, and Cerámica armada, which addressed reinforced structures (Figure 5). Campos led these investigations. Although he is known for his design, with engineer Maximino Isoba, of the Cuban Pavilion at La Rampa in 1963, scholarship has overlooked Campos’s work for MICONS on thin-tile vaults. These two publications not only provided in–depth explanations of the reasons for ceramic shell research but also detailed the labor, tools, materials, load tests, structural systems, and building typologies involved, and presented built examples as well.

From the outset, the MICONS publication Cerámica convencional acknowledged the “conventionality” of thin-tile vaults, in contrast to the “futuristic” technique of prefabricated reinforced concrete construction. However, the MICONS research team justified the use of this conventional brick construction, given the lack of available steel for rebar and wood for concrete formwork. The need to support the existing Cuban brick industry was another key reason for the continued use of ceramic elements. The emigration of many builders and manufacturers following Cuban nationalization stoked fears regarding an imminent loss of construction knowledge and further highlighted the significance of traditional brick construction techniques. Cerámica convencional described the brick industry as follows: “The technique, known for many centuries, was known only through tradition, and many of its secrets were lost when these were interrupted and substituted by more practical but less noble methods. Our interest in using all of these laborers and methods, in addition to better understanding their historical function, led us to investigate the artisanal technique of employing brick and tiles for roofs and slabs.”

The training of labor accompanied the experiments in constructing thin-tile vaults, with a school for tile masons (ratilleros) organized in El Patio del MICONS. Training took place in different sites around Cuba, so that “while the research staff conducted experiments, they also trained groups to work on them.” The training provided on project sites, such
as at the National Art Schools, was intended to give masons an opportunity to master the tools and skills they needed as they built arches spanning 2 to 3 meters. The training at the research center, in contrast, explored new possible typologies, uses of materials, and reinforcement methods. This led to the emergence of an inevitable and close collaboration between builders and designers as they constructed, tested, and analyzed these structures (Figure 6).
In its report *Cerámica convencional*, MICONS highlighted an implicit relationship between tools and skill, alluding to an urge to improve and systematize the traditional methods of vault construction. As the builders’ learning progressed, so did the relationship between labor and tools in vaulting: “Work was carried out with full formwork first, then with simple sliding wooden formwork, then with formwork and strings, and finally building in the air.” The MICONS report precisely quantified the relation of labor to time: to construct a brick vault of 1 square meter with a second layer of tile vault required 27 bricks, 27 tiles, 0.03 cubic meters of wood for formwork, 4 kilograms of rapid cement, 0.05 cubic meters of mortar, and one and one-half hours of one laborer’s time. The same report also emphasized the use of local resources. The bricks, tiles, and mortars used for the MICONS experiments were the same materials found in the wider Cuban construction market. Following the vault’s construction, load tests were performed using cement blocks of 31 kilograms; both uniform and concentrated symmetric and asymmetric loads were tested (Figure 7). The test results were contrasted with structural analyses of vaults constructed using rules of thumb, fundamental equations, and form verification through graphic statics. After defining the span and height, engineers used graphic statics to modify the vault’s shape and thickness in order to maintain the line of thrust in the middle third of the vault (usually resulting in a catenary section).

The team in the courtyard built two families of vaults: single-curved, or barrel, vaults and double-curved surfaces such as sail vaults and domes. For small to midsize spans of less than 8 meters, MICONS research suggested barrel vaults, built with robust formwork. The use of formwork offered...
three key advantages related to labor. First, the construction of vault formwork required only moderately skilled labor. Second, the interior of the vault could be finished during construction itself. And finally, this construction technique facilitated mass production of identical vaults.

For spans that exceeded 8 meters, sail vaults were recommended. Unlike barrel vaults, sail vaults feature curves (and transfer loads) in two directions, offering greater stability and facilitating vault construction. To convert a barrel vault into a sail vault, the MICONS report suggested constructing fixed formwork along one side of the span and a mobile formwork on guiding rails on the other. By moving the mobile formwork over the curvature of the fixed formwork, builders could generate the complex double curvature of a sail vault (Figure 8).44

Trials of double-curved structures were built in El Patio del MICONS with minimal formwork (Figure 9). The simplest double-curved structure built in the courtyard was a 4-by-4-meter sail vault on a ring beam, a reinforced concrete frame that supported the vault (Figure 10). Like all of the small vaults and arches built, this two-layer vault was load tested. The second double-curved structure was also a square sail vault, this time 6 by 6 meters and sprung from buttresses instead of a ring beam. To this vault, the designers added eaves (aleros) along the edges as countercurves, with the liplike shape of the eaves more cantilevered at the middle than at the corners. The 6-by-6-meter base was also used to explore an inverted paraboloid hyperbolic surface forming a subtle dome geometry. Another, more geometrically pronounced dome had a corrugated surface of radial hexagonal vaults; MICONS reports referred to this structure as the Jardinera (Planter Pot).

The largest double-curved structure to be built in the MICONS courtyard was a 15-meter sail vault. This span was the maximum size documented in the investigation’s tables.
regarding vault characteristics and specifications. Construction of the 15-meter shell required both side and diagonal formwork. Like the 6-meter version, the sail vault had cantilevering aleros, but with less proportional projection. There were six layers of tiles at the edges and two in the center. The buttresses receiving the vault were visually light and elegant, made of brick with angled support from reinforced concrete tied by invisible underground tension rods. This sail vault demonstrated the structural efficiency and material optimization of catenary sections, different layers of tiles, and lightened substructure. Campos’s investigation group determined through a design and experiment process that a 15-meter sail vault could achieve this efficiency. The only thin-tile vault structures at the National Art Schools to achieve a greater span, without using concrete ribs, are the workshop domes at the School of Plastic Art, designed by Ricardo Porro. Surviving literary and visual evidence indicates that a wide variety of vaults were built in El Patio del MICONS (Figure 11).

The MICONS technical investigation team generated standardized designs for vaults in the form of tables published in Cerámica convencional, aimed at architects, engineers, and builders. The tables documented vault span-to-rise ratio, section and layer details, elements such as tension rods and ring beams, and details of guidework and formwork (Figure 12). The formwork table provided construction details and drawings of formwork for different spans, which were rigorously followed in the construction of the large 15-meter sail vault in the courtyard (Figure 13). The MICONS regulation tables guided the construction of many vaulted projects in Cuba, and today they provide us with a useful tool for analyzing these buildings (Figure 14).

Systematizing Thin-Tile Vaults

While scholars have long assumed that knowledge of thin-tile vault construction passed from the designers of the National Art Schools to MICONS, it appears instead that knowledge generated at MICONS informed the design of the National Arts Schools. The experiments conducted in El Patio del MICONS focused on two families of vaults: small to midsize single-curvature vaults suitable for houses and schools, and midsize to large double-curved vaults for pavilions and large halls. By reducing the design of vaults in the first category to basic rules of thumb, Campos’s team proposed simple
Figure 10  MICONS, vaults realized in El Patio del MICONs, Havana, 1960–65 (Ministerio de la Construcción, Cerámica convencional [Havana: Dirección de Investigaciones Técnicas, Ministerio de la Construcción, May 1965]); Centro de Documentación, Empresa RESTAURA, Oficina del Historiador de la Ciudad de La Habana).

Figure 11  All types and sizes of unreinforced tile- and-brick vaults built in El Patio del MICONs, Havana, 1960–65 (authors’ drawing).
compositions with repetitive, modular forms that could be produced systematically.

In contrast, the design of large-span vaults represented an opportunity to push the limits of thin-tile vaulting. One of these vaults was the corrugated hexagonal dome known as the Jardinera. Studies on the National Art Schools have cited picture soft his dome evidence that Gumersindo demonstrated the value of thin-tile vaulting to MICONS personnel. However, this claim fails to explain the presence of plans, sections, and perspectives in the MICONS research report, suggesting that ministry staff may have drafted and even designed the Jardinera. Whoever built the dome did not intend to use it as a prototype for modular vaulting: it was not load tested, and it was not recorded in studies of vault construction conducted by the MICONS teams. While the MICONS report mentioned this dome only briefly, the Jardinera informed the language of domes and vaults used at the National Art Schools, as revealed in our digital modeling of the dome using the schematic plans and sections in the MICONS report (Figure 15). The geometric articulation of this structure helped to guide Porro’s design for the main halls in the School of Modern Dance as well as Garatti’s design for the unbuilt central hall of the School of Music. Like the Jardinera at El Patio del MICONS, these domes featured corrugated surfaces, but with reinforced concrete ribs located at their intersections.

Although the MICONS studies led by Campos sought to demonstrate the different applications of thin-tile vaults, their primary purpose was to enable MICONS to provide rigorous guidance for the systematic, labor-led construction of simple, modular elements, allowing for the mass

Figure 12 MICONS, standardized design for parabolic vaults with a table of thicknesses corresponding to different spans and details of layers and stiffening arches, 1965 (Ministerio de la Construcción, Cerámica convencional [Havana: Dirección de Investigaciones Técnicas, Ministerio de la Construcción, May 1965]).
Figure 13  MICONS, table for a tile vault formwork’s dimensions, bracing, and details for different spans, 1965 (Ministerio de la Construcción, Cerámica convencional [Havana: Dirección de Investigaciones Técnicas, Ministerio de la Construcción, May 1965]).

Figure 14  Verifying the implementation of formwork standardization (authors’ drawing superimposed on an image from Centro de Documentación, Empresa RESTAURA, Oficina del Historiador de la Ciudad de La Habana).
production of houses and schools in a conventional or partially prefabricated manner. As attested by the many surviving vaulted projects in Cuba today, MICONS achieved this goal.

One Model, Many Times: Housing, Schools, and Other Projects

As the staff at MICONS investigated thin-tile vaulting practices, they also developed building prototypes across Cuba that could be built using modular elements fabricated on-site. These early investigations of modular design and the mix of conventional construction with off-site and on-site prefabrication of building components, known as semi-prefabrication, generated a much richer body of methods than the full prefabrication approach subsequently adopted by industrialized building manufacturers. The design method adopted at MICONS encouraged dialogue between the teams that carried out phases of investigation and those responsible for implementation. When an investigation team proposed a new building prototype, other architects were responsible for its implementation, and in the process, the same structural elements were often used to generate varied solutions. For example, a housing block might make use of standard vaulting systems, but different iterations of the same project varied the positions of the walls and openings to create different interior spaces and exterior façades.

Several state entities administered the housing supply in postrevolutionary Cuba. One of the leading agencies, the National Institute of Savings and Housing (Instituto Nacional de Ahorro y Viviendas, or INAV), maintained the conventional construction methods developed prior to the revolution, focusing more on the delivery of high-quality houses than on experimenting with mass housing production. In contrast, the Center of Technical Investigation at MICONS focused on construction technology to achieve cost-effectiveness, minimize construction time, and improve manufacturing and maintenance methods. Within the center, Campos headed a team that took on yet another experimental pilot project, this time for housing blocks in Altahabana, south of the capital.

A study of Campos’s work on the houses was published in 1964 in a report titled Viviendas urbanas, which examined seven experimental buildings constructed in Altahabana from 1961 to 1964. The buildings, which became models for diverse housing projects in Cuba, were three stories tall and featured two apartments with symmetrical plans on each floor. While in the first three buildings load-bearing walls running the length of the buildings supported prefabricated flat concrete panels on transverse beams, the fourth building featured a thin-tile vault roofing system constructed with locally produced ceramic materials (Figure 16). Unlike the lower floors, with their prefabricated flat brick panels on beams, the top floors featured vaults spanning 1.5 meters. This design became a standard that would be repeated elsewhere in Havana and in eastern Cuba, at Manzanillo. Its success was linked to the cost-effective use of prefabricated elements as well as the use of partition walls that allowed for flexible interior layouts.

The design of the fifth and sixth buildings in Altahabana’s experimental project marked a turning point: the direction of the load-bearing wall changed from parallel with the façade to perpendicular, offering three bays, each 3.5 meters wide for each apartment (as opposed to the more timid 1.5-meter span of the vaults in the fourth building project), thus creating a larger, flexible living area. Again, only the top story featured thin-tile vaults, with prefabricated panels used for the lower stories. Built using a movable (sliding) formwork of a parabolic section, with one layer of brick and one layer of tiles, this vaulted solution corresponds to the table of vaults included in the MICONS report.
The success of the sixth building led to its use as a prototype. The MICONS architects, drawing upon their experience with Altahabana, repeated the design throughout the country, although they varied construction methods as well as the placements of openings and the locations of staircases. Three main residential areas in Havana itself were developed using this typology. In Vedado, architect A. Cauto Ramos used thin-tile vaults with sliding formwork. In the Plaza de la Revolución, architect Angel Cuervo built twenty-four housing units, constructing vaults on full wood formwork. Urban houses with thin-tile vaults were also built in Ciudad de la Construcción by Antonio Quintana (Figure 17). The project began in 1960 before MICONS inaugurated its vault studies, and the original proposal lacked thin-tile vaults completely. Ciudad de la Construcción introduced the idea of the house as a right and not a privilege; the project was conceived as a revolutionary architectural and urbanistic challenge to capitalism, a “city” of high-quality public housing surrounded by abundant green space. However, the notion of such progressive and luxurious public housing was soon met with serious criticism, including from Che Guevara himself, and severe budget cuts followed. After the plans for Ciudad de la Construcción were revised extensively in 1961, thin-tile vaults were introduced as a way to ensure greater cost-effectiveness.

Quintana designed the first floors of his vaulted housing blocks as open public spaces, with load-bearing walls supporting catenary arches, stairs outside the building envelopes, and thin-tile vaulted roofing systems on the top stories. The roofs of the row houses were also thin-tile vaults, as was the roof of the primary school building. These were all constructed brick vaults of a catenary section. Although the original plan envisioned 200 hectares, only 16 hectares were built from 1961 to 1964.

Even before Quintana created the vaulted housing at Ciudad de la Construcción, Enrique Cano designed rural vaulted houses at Alamar, in east Havana (see Figure 17). MICONS built about four hundred of these houses, with eight building types, six featuring thin-tile vaults and two with reinforced concrete slabs. Of the structures with vaults, three were single-family units and three were duplex units. Similar to the approach at Ciudad de la Construcción, these designs were conceived as high-quality housing with large gardens and vaulted covered areas for parking. Their thin-tile vaults were all made of brick and cement built over full modular formwork, supported by ring beams. The vaults of two of the houses, different from all the others at Alamar, recall the bird-wing-like vaults built by Campos in Camagüey.

More than 2500 schools were built in Cuba from 1961 through 1964, attesting to the priority given to the educational
system following the revolution. The demand for new facilities encouraged both modular design and the investigation of mass-production systems that would allow schools to be built rapidly and off-site. The architects who worked on the early models for schools discovered, as did those who worked on housing, that they were given generous design autonomy; later, however, this gave way to a much narrower focus on industrialized elements. From the outset, these investigations involved the use of ceramic materials.

The earliest education facility to use thin-tile vaults was the Círculo Infantil childcare center in Havana, which was designed by Marta Ontiveros (Figure 18). In addition to its tile vaults resting on beams connected with steel ties, the building featured an innovative U-shaped plan. Mario Girona (1924–2008) developed a school design that made extensive use of thin-tile vaulted classrooms. The prototype had modular plans that could accommodate seven different grades in seven, fourteen, or twenty-one classrooms. Girona’s design consisted of five long parallel rectangular bays with barrel vaults resting on load-bearing walls. Two empty bays at the center functioned as a courtyard for outdoor classrooms.

Girona’s design provided a model for schools across the country. In Havana, the highest concentration of vaulted schools was in Marianao, to the west of the city center, where at least five of these schools can still be found today. The schools of Marianao were among the earliest to feature thin-tile vaults, and the plan on which they were based became an important prototype for other parts of Cuba. However, the awkward layout of both the classrooms and the circulation areas generated criticism. An improved version of this plan, implemented mostly at secondary schools, arranged the vaults perpendicularly around a central courtyard and allowed the vaults to project from the exterior walls to create covered exterior areas for outdoor activities. At the same time, the smaller size of the classrooms and the shorter length of the vaults reduced the incidence of cracking.
Cerámica convencional documented this design as the work of Dorta Duque. These experiments in school design continued at MICONs under the direction of Josefina Rebellón, who also designed and built secondary schools with thin-tile vaults in Minas, Camagüey (see Figure 18).

A 1965 report on the construction of schools in Cuba pointed to the widespread use of thin-tile vaults for school buildings. The report identified numerous shortcomings of thin-tile vaults, beginning with the fact that builders lacked sufficient experience in constructing them; the vaults themselves needed better waterproofing, they created acoustic problems, and they could not be cantilevered and thus could not be used for covered outdoor passages. Finally, the report noted, vaults were prone to cracking. Yet the report also emphasized that the use of thin-tile vaults for educational buildings had certain advantages: it helped to address the problem of material scarcity, it involved the local community in construction, and it allowed for the integration of a variety of different materials, including concrete, brick, and tile.

Another early initiative following the Cuban Revolution involved the transformation of military camps and barracks into educational facilities. In addition to converting roughly thirty small military barracks, known as cuarteles, into schools, designers proposed to transform six large military camps into school complexes and other kinds of educational institutions; these camps included the former U.S. Army base Camp Columbia, near Marianao in the western part of Havana. Unlike the elite golf course appropriated for the construction of the National Art Schools, Camp Columbia was reconceived as an educational center called Ciudad Libertad (Liberty City). Planners intended to accommodate eight thousand students in schools and recreational areas on the site. Of the existing structures rehabilitated for those purposes, most were roofed with thin-tile vaults. Ciudad Libertad, just 2 kilometers from the site of the National Art Schools, was also the site for another educational center built with tile vaults; in 1961, at the same time the National Art Schools were under construction, Josefina Rebellón, then a third-year architecture student, undertook the design of a high school named Centro Preuniversitario (Figure 19).

Everyone with skills in architecture had a role in the construction of postrevolutionary Cuba. As Rebellón later recalled, “Most of us were students or newly graduated architects. The practicing architects left the country.”

Rebellón faced the challenge of generating a complete design in five months. Half of the 4,500-square-meter complex that she designed was roofed with thin-tile vaults; the other half was covered with concrete slabs. She divided the complex into three sections: two circular buildings featuring thin-tile vaults, separated by an undulating linear two-story classroom building. This design facilitated breaking the construction into phases, with the classrooms in the central linear part to be completed first, then the laboratories in the northern cluster, and finally large seminar rooms and the library in...
the southern cluster. Rebellón’s original design specified thin-tile vaults for the entire complex; however, although the building site employed workers with MICONS training, MICONS did not provide enough of these skilled masons to finish the project on time. Rebellón decided instead to use reinforced concrete flat slabs for the central linear section of classrooms. In January 1962, the project was inaugurated on schedule.

The 2,500-square-meter circular buildings containing large teaching seminar halls and laboratories had conical vaults with sequences of catenary-section arches. Most of these vaults were built with two layers of tiles with dimensions of 120 by 240 millimeters and about 30–40 millimeters in thickness. The largest vault had a span of 10 by 5 meters. The span of the smaller vaults decreased from 5 meters to 3 meters. All of the vaults sprang from beams that shaped the intersection between the conical vaults. Each joint between the beam and vault had an extra layer of tiles for waterproofing. Continuing into outdoor spaces, the vaults became part of the landscape of the building. The openings in the façades were made with voided decorative ceramic blocks called celosia, enhancing the building’s visual and functional permeability and its integration with its surroundings.

Rebellón’s designs did not stray far from the standards that resulted from the thin-tile vaulting research. For example, her use of reinforced concrete beams and thin-tile vaults, as well as her ceramic façade designs, recalled Cuervo’s housing blocks in the Plaza de la Revolución. However, Rebellón’s building demonstrated the flexibility that vaulting systems offered for such modular layouts. The change from barrel to conical vaults was possible because these were the only elements to be constructed on-site, and the builders could adjust these forms for complex geometries without introducing complications for the rest of the project.

Thin-tile vaults were also used for factories, beachfront hotels, restaurants, and cooperative centers. The single-story thin-tile vaults used for hotels in Playa Giron and Playa Ancón became models employed at many Cuban beaches (Figure 20). The hotel in Ancón is currently scheduled to be replaced by a new building, and the outdoor vaulted canopy is the only structure still standing on the site. Two thin-tile vaulted designs for cooperative cafeterias were also distributed across the island: the first, as at Ciego de Avila and Granma, was a pavilion of six half-circle barrel vaults on two parallel beams, with a small block for services and storage placed at the rear. The second model was much larger, like

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Figure 19 Josefina Rebellón, Centro Preuniversitario, Ciudad Libertad, Havana, 1961–62 (drawings, Centro de Documentación, Empresa RESTAURA, Oficina del Historiador de la Ciudad de La Habana; photos, Arquitectura Cuba, no. 334 [1965]).
the cafeteria at El Rosario in Pinar del Río, comprising four bays, with each vault spanning around 8 meters, and with two service zones placed at a lower level. A truncated vault extended over a terrace. Today, the Pinar del Río cafeteria is in ruin.

**T**radicional **M**ejorado, or Improved Traditional Construction

The construction of the National Art Schools began in September 1961 and continued for about four years, when support for the project declined and it was left unfinished. The scholarship has emphasized that the construction at the National Art Schools marked a shift from traditional building methods, including thin-tile vaults, to imported prefabrication methods. However, by considering the research on thin-tile vaults conducted by MICONS, we can gain a more nuanced understanding of these vaulted structures’ relationship to prefabrication during the first half of the 1960s. It is clear that MICONS valued thin-tile vaulting, as attested by its active role in advancing thin-tile research and construction all around the island. Thin-tile vaults did not represent prefabrication’s antithesis, nor were thin-tile vaults part of a passive inheritance of conventional construction practices dating from before the revolution. Indeed, although the industrialization of the construction site started as early as 1960, this did not ignore the methods adopted on the conventional prerevolution construction site, called tradicional, as attested by the work of INAV. During the vibrant years of 1960–65, MICONS enabled modern building practices to meet and merge with on-site construction.

As a result, between prefabricado and tradicional, a new and interesting category emerged: tradicional mejorado, or improved traditional. This category is often associated with concrete ceiling systems. Yet the thin-tile vaulting projects of MICONS also belong in this category. In the report *Viviendas urbanas*, the description of the experimental work in Altahabana defines the improved traditional, stating that the housing blocks are “experimental housing . . . of conventional and traditional systems with semi-prefabrication, which constitute the improved traditional [system].” If improved traditional can be defined by the scale and number of its prefabricated elements, a better definition would be prefabrication without complete mechanization. Tradicional mejorado depended more on the skill of the builder than on mechanical power.
While building regulations governed both traditional and industrialized methods, these regulations revealed a certain elasticity regarding the varying resources and labor skills available in different regions. Technical reports on thin-tile vaulting also served as documents that helped to codify vault construction. Curiously, these reports codified and systematized the formwork rather than the vault itself: the processes of mechanization and codification neglected the vault as a handmade product of skilled labor. One result of this elasticity was the regulation of building components made on-site. Another result was the production of light and easily transportable components for use as concrete slabs and beams, while walls were built on-site with local bricks. However, the advent of centralized construction practices in 1965 led to the utter transformation of this hybrid and design-oriented approach to prefabrication in Cuba. The 1963 congress of the International Union of Architects (UIA, from the French, Union Internationale des Architectes) in Havana signaled the first move toward this centralized approach.

The UIA Report of 1963

The period 1963–65 marked a phase of reflection on Cuba’s first years of construction after the revolution. The UIA congress, titled “La arquitectura en los paises en vía de desarrollo,” or “Architecture in Developing Countries,” took place in Havana in 1963. As summarized in the conference proceedings as well as in a 1964 special issue of Arquitectura Cuba, the conference affirmed the need for a rigorous and critical analysis of the architecture of the early period after the revolution (from 1960 to 1963). Additional articles advocating for such analysis continued to be published in Arquitectura Cuba through 1965, alongside reports from conferences such as the National Seminar of Housing and Congress of Construction, held in October 1964.

Examining these reports, Cuban architects could view early investigations into thin-tile vaulting as providing a temporary solution for construction problems in Cuba. Such an assessment was supported by no other than Fidel Castro, who said in a speech delivered to the UIA, “Our aspiration [to provide houses for the people] is limited by the capacity of our construction industry.”

Every Cuban deserved housing, and thus the method of production had to change, as large-scale housing development could not be achieved through small, isolated construction projects carried out in the traditional manner, especially when hampered by a scarcity of materials and labor. The lack of these necessities contributed to a gap between the ideal and the reality, a problem that Castro translated as follows: “We must confess that we were also rather subjective at the beginning. During the first years of the Revolution, we often confused reality with desire.”

To solve these problems, it was necessary to centralize construction practice under state authority. Other agencies studying rural housing and construction were later merged with MICONS. With the goal of “total mechanization of construction,” the use of industrial building components with production centralization would transform and recalibrate both production and needs. The total industrialization of construction also had ideological implications for the role of the worker versus the role of the architect. The UIA report of 1963 stated that while the revolution changed the role and the clientele of architects, the tools and models of architectural practice remained similar.

The report predicted that the mechanization of construction “will represent a change of scale in all aspects of [the architect’s] work. The projects will not be based on small elements such as the cement block and the traditional brick, but take into account the possible ideas that allow the use of grand elements and panels. . . . The new structuring of the society’s life will produce the role of joint architecture as one of the main features of our architecture in this stage.” Mechanized architecture was seen as offering an “opportunity” for the exploration of new and revolutionary possibilities, not unlike today’s applications of 3-D printing and robotic construction. These new social, economic, and technical conditions set in motion by the revolution posed a “historical challenge to architects: to create a new architectural and human language in an epoch when the architect for the first time delivers his work to the whole society.”

This approach also implied a veiled criticism of the “traditional” and “improved traditional” modes of construction. In its analysis of the improved traditional method, the UIA asserted that while it had a positive role early on, it was not suitable for nationwide application because of the uneven distribution of building skills across the island and the length of time required for construction. It was an acceptable mode for the time being, but it was temporary and transitional. In 1965, Hugo D’Acosta published a summary of the work of the Center of Technical Investigation in Arquitectura Cuba, in which he described three eras of construction in Cuba: the past construction of capitalism, the present investigation of possibilities, and the future application of the chosen solutions. D’Acosta’s review made timid mention of thin-tile vaults, contrasting prefabricated concrete construction with ceramic work executed for schools and houses. According to D’Acosta, thin-tile vaults did not qualify as a useful technique for future construction. He stated that in 1964 the tradicional mejorado would reach its conclusion, and then full industrialization would begin. Perhaps it was not a mistrust of thin-tile vaulting that caused the decline of this building technique, but an exaggerated belief in prefabricated concrete construction.
Thin-Tile Vaulting in Cuba since the 1960s

As scholars such as Juan de las Cuevas Toraya and Roberto Segre have argued, the experiments that occurred under the supervision of the Center of Technical Investigation not only suggest the need for a more nuanced understanding of MICONS’s approach to construction but also challenge the conventional notion of an ongoing battle between opposing technical and artistic approaches to architecture in Cuba in the 1960s. Although MICONS analyzed thin-tile vaulting intensively, these investigations have largely been forgotten or omitted from studies of construction history in Cuba. This amnesia has also affected more recent approaches to thin-tile vaulting in Cuba. During the economic crises of the 1990s and early 2000s, the island again experienced scarcity in construction materials. Thin-tile vaulting reappeared in buildings as part of what became known as the movimiento de viviendas de bajo consumo material y energético (the movement for houses using low material and energy consumption). Unlike in the 1960s, the use of these materials was not thoroughly investigated structurally or architecturally. Furthermore, the movement made no mention of the work of MICONS on thin-tile vaults only thirty years prior, which occurred in similar economic circumstances.

Figure 21 Locations of vaulted projects in Havana (authors’ drawing).

Thin-Tile Vaults: Both Futuristic and Scarcity Driven

While recent studies have demonstrated how architects, engineers, and contractors helped to transfer the thin-tile vaulting technique from Spain to Germany and Belgium, this study adds to our knowledge of the history of thin-tile vaulting in the Americas. The Center of Technical Investigation, now located in east Havana, has conducted a study of a slab system solution with thin-tile vaults built of cement-stabilized earth over a sliding mold. Today, thin-tile vault construction in Cuba is linked only to restoration projects directed by the vocational school Gazpar Mechlor Escuela Taller, as part of the Office of the Historian of the City of Havana. The school has no link to Campos’s 1960s investigations.

The first five years after the Cuban Revolution represented an exceptional period when building practices were
informed as much by technical futuristic visions as by scarcity-driven realities. For the first time, a systematic investigation of thin-tile vaulting addressed the technique as a key building component. Campos played an essential role in the investigation and implementation of vaulted buildings for MICONS, exploring the use of traditional and reinforced ceramics and building the first vaulted urban housing in Altahabana as head of the teams working for the Center of Technical Investigation. During our research, we identified and mapped these and the other thin-tile vaulting projects discussed in this essay (Figure 21).

Campos and his team introduced the use of bricks to MICONS buildings, including the National Art Schools. However, unlike other MICONS projects, at the National Art
Schools, the various schools’ designers pushed the available materials and building techniques to explore unique and complex geometries. And yet this construction was not always of the highest quality: many of the shells used thin-tile vaults only as fill between extensive reinforced concrete beams or relied on redundant substructures. Furthermore, although some of the school’s vaulted structures were modular, many other vaults were constructed as unique individual elements. In contrast to the designers of the National Art Schools, MICONS architects were interested in rationalization, emphasizing modular solutions generated by a single unit’s repetition. This had important construction implications, as unskilled workers could build many single-curved barrel vaults using molds or light formwork. Although not as architecturally and geometrically exceptional as the National Art Schools, houses and schools with thin-tile vaulting were possible because the vaults were conceived as repetitive and easy-to-build elements.

Between these extremes lies the example of Rebellón’s thin-tile vaulted school in Havana, representing a negotiation between the architect and the project’s complex geometry and repetitive forms. Rebellón’s design, the work of a then third-year architecture student, used the same MICONs elements, including prefabricated beams, load-bearing walls, and thin-tile vaults. However, because the thin-tile vaults were built in place, they could be repeated as the segments of a circle, as single-curved barrel vaults made into conic shapes. Many roofing systems in Cuba appear to be thin-tile vaults like those used at Rebellón’s school. We anticipate that further examination will support our claim that thin-tile vaults were an essential component of the work conducted by MICONs in the early 1960s that has since been largely forgotten.

Work has also recently begun on a project to protect and restore the National Art Schools. The study of thin-tile vaulted buildings presented in this essay coincides with this effort and demonstrates that both the construction techniques and the structural system employed at the National Art Schools were consistent with many Cuban building projects at the time. It is important that rather than emphasizing the uniqueness of the National Art Schools, scholars consider these buildings as evidence of an innovative mode of construction that was used more broadly and produced many structures currently in need of documentation—and that may be the focus of future studies on the history of vaulting in Cuba.

In this article, we have examined the standardization of thin-tile vaults in relation to state-led building strategies. Although the early improved traditional model, combining modular semi-prefabrication of light elements with in situ craft-based building, was successful, later centralization of building was less able to accommodate thin-tile vaulting, which combines craftsmanship with industrial processes and, as a result, resists abstraction, codification, and decontextualization. The tradicional mejorado model is still relevant for tackling current construction challenges. What makes this model important is that it uses technology not simply to produce building elements but also to improve the dialogue between specific site conditions and the builder’s set of skills. Rather than seeking to replace builders with technology, the tradicional mejorado model facilitates the accessibility of technology to builders. It thus brings together two extremes in design, where the scarcity of resources meets an abundance of solutions.

The methodology used in this research, which has relied on both drawing and 3-D modeling, as well as familiarity with actual construction techniques, has enabled us to reconstruct these elements as part of a genealogical tree of thin-tile vaulting in Cuba (Figure 22). This genealogy allows us to document the temporal, geographical, and geometrical conditions of almost every vault that we have uncovered in the archives. In this kind of investigation, drawing and modeling offer essential tools for both understanding and communication.

M. Wesam Al Asali is a researcher at the Centre for Natural Material Innovation and a practicing architect. He investigates the history of construction, building crafts, and fabrication technologies in the context of climate emergencies, with the support of funding from the Arts and Humanities Research Council (AHRC), the Arab Council for the Social Sciences (ACSS), and the Arab Fund for Arts and Culture (AFAC). He currently leads IW-lab, his architectural practice, and CERCRAA, an innovation platform for building crafts based in Valencia, Spain. https://orcid.org/0000-0001-8782-216X

Dania González Couret is an architect (1979) and a full professor at the Universidad Tecnológica de La Habana (CUJAE); she received her PhD in 1994 and her doctor of science degree in 2007. She is a member of the Cuban Academy of Science and president of the National Court of Doctorates for Architecture and Urbanism. She has authored more than two hundred articles, papers, and books on Cuban architecture, social housing, and environmental design in Cuba and beyond. http://orcid.org/0000-0002-1406-4588

Michael H. Ramage leads the Centre for Natural Material Innovation at Cambridge University. Trained as an architect and an engineer, he is currently involved in research focusing on the development of low-energy structural materials and systems in masonry, the improvement of housing in the developing world, and the improvement of engineered timber and bamboo through natural material innovation. https://www.arct.cam.ac.uk/people/mhr29@cam.ac.uk

Notes

1. We thank Orestes de Castillo for his help during our early research from Madrid, María José Pizarro (Universidad Politécnica de Madrid) for sharing her archives of vaults in Cuba, and Humberto Ramírez (UNAICC), Samuel Rolando, and the late Maximino Bocanaldo (former head of the Center of Technical Investigation) for facilitating our research in Cuba. We also thank...
Ruslan Muñoz Hernández (CUJAEE) and the staff at Restaura Library and Rubén Martínez Villena Library for facilitating our archival work. We dedicate this essay to the memory of Edward Allen.


5. Architects such as Antonio Gaudí (1852–1926) and César Martínez (1888–1973) used thin-tile vaulting for expressive constructions. In the years after the Spanish Civil War, vaults were evident in the work of Luis Moya Blanco (1904–90).


7. Studies of thin-tile vaults in the Americas present varied cases. The oldest is the work of Fiar Domingo de Peterses, a Valencian missionary and master mason who used the technique in his buildings in Colombia in the late eighteenth and early nineteenth centuries. See Ochsendorf, Guastavino Vaulting.


15. After the abandonment of their construction, the art schools were often referenced as projects of exploration, expression, and individuality. Such rhetoric appears in Roberto Segre’s discussion of the schools in his 1989 book Arquitectura y urbanismo de la revolución cubana. Before Segre, representatives of the Generation of the 1980s used the schools as examples when they argued against the Cuban use of prefabrication systems. See Segre, Arquitectura y urbanismo de la revolución cubana, 123; Loomis, Revolution of Forms, 151.

16. Until 1963, the Ministry of Construction was named the Ministry of Public Works (Ministerio de Obras Públicas, or MINOP). For consistency, we use the acronym MICONS for the Ministry of Construction throughout this article, regardless of the period under discussion.

17. Roberto Segre uses the schools as an example of the two contesting approaches to architecture in Cuba after the revolution: one of adopting technological advances, represented by Fernando Salina’s approach to prefabrication; and one of advocating for artistic and aesthetic values in design, as in the work of Porro in the National Art Schools. John A. Loomis concludes from interviews with the schools’ architects that MICONS had no knowledge about thin-tile vaulting and its constructional possibilities. See Roberto Segre, “Los años 60 y el Congreso de la UIA,” Arquitectura y Urbanismo 24, no. 3 (2003), 29–34; Roberto Segre, Diez años de arquitectura en Cuba revolucionaria (Havana: Ediciones Union, 1970), 83; Loomis, Revolution of Forms, 112; Santiago Huerta, “The Mechanics of Timbrel Vaults: A Historical Outline,” in Essays on the History of Mechanics, ed. Antonio Becchi, Massimo Corradi, Federico Foco, and Orietta Pedemonte (Basel: Birkhäuser, 2003), 89–134.

18. Cuba’s thin-tile vault tradition is evident throughout the Old City of Havana, in public buildings, churches, and housing blocks featuring vaulted stairs and revestimientos (ceilings on small barrel vaults on beams). The oldest reference to such vaulting that we could trace dates to 1954. The architect, Abel Fernández Simón, mentioned rectangular tiles that were called “Catalan tiles” or “tiles of Gerona,” which were used extensively in the construction of stairs and terraces. See Juan de las Cuevas Toraya, with Gonzalo Sala Santos and Abelardo Padrón Vallés, 500 años de construcciones en Cuba (Madrid: Chavin, 2001), 50. The only mention we could find about the work of the Ministry of Construction on thin-tile vaults before the National Art Schools was one by Eduardo Luis Rodríguez in 2000, explaining the use of tiles and brick in the schools as a systematic choice that emanated from the work of the Center of Technical Investigation at MICONS, which was led by Hugo D’Acosta Calheiros. See Juanas et al., “Una nueva expresividad de las bóvedas tabicadas,” 80, 81.


20. Since 1980, the National Art Schools have fascinated scholars interested in modern Cuban architecture as well as architect-restorers hoping to complete the schools. The ruinous condition of the unfinished structures has magnified, and sometimes romanticized, the significance of their architecture as well as their material construction, including their use of thin-tile vaults.

21. Our methodology was as follows: we modeled each of the vaults and buildings that we identified during our research and then inserted annotations to record chronology, location, geometry, and construction techniques. In this way, we were able to generate new relationships between buildings and thin-tile vaulting systems.


24. Regional, rural, and urban planning took place in the MICONS Department of Planning (Departamento de Planificación Física). For the construction of new rural and urban housing units, three separate governmental entities were created: Instituto Nacional de Ahorros y Viviendas in 1959, Viviendas Campesinas in 1960, and Dirección de Viviendas Urbanas in 1961. Help for inhabitants who needed to rehabilitate existing houses was provided through the program Ayuda Mutua y de Esfuerzo Propio, which was part of the 1959 plan to eliminate unhealthy urban neighborhoods. See International Union of Architects, *Cuba*, 35; Ruslan Muñoz Hernández and María Victoria Zarzoya Loureda, “Las ‘Casas de Pastorita’ en La Habana,” *Arquitectura y Urbanismo* 37, no. 1 (2015), 39.

25. In Cuba, 1960 was pronounced the year of education, and illiteracy was eliminated among more than one million persons, most of whom lived in remote villages. The Ministry of Education was partially responsible for school construction and repair. Zarzoya Loureda, “La arquitectura educacional de los sesenta en Cuba,” 9.

26. By working in small groups that were dispersed across governmental agencies, architects could rethink how buildings might be built and what they might offer, as opposed to concentrating on restrictive codes—although increasing centralization would later bring this approach to an end. Samuel Rolando, interview by M. Wesam Al Asali and Dania González Coutret, Nov. 2018.


28. The factory was owned by the Azorín family before the revolution; it was expropriated by the government in 1960 and renamed the Antonio Suárez Domínguez factory.


30. In the test of vaults in Santiago de Cuba, a comparison was made between two barrel vaults, one of concrete and one of bricks, both loaded and observed. The tests were conducted by Viviendas Campesinas, the agency within the National Institute for Agrarian Reform (Instituto Nacional de Reforma Agraria) that dealt with rural housing.

31. Ministerio de la Construcción, *Cerámica convencional*, Ministerio de la Construcción, *Cerámica armada*.

32. Campos joined MICONS in 1959 and worked in the Center of Technical Investigation until he departed for Miami in the late 1980s. Much of his work on ceramic experimentation took place from 1960 to 1962, and his reports appeared in MICONS publications from 1962 to 1965. In 1965, MICONS published numerous reports, in addition to *Cerámica convencional*, presenting the results of many of the center’s investigations, including one of thin-tile vaulting; this compilation of five years of diverse research could be considered the opening of a new phase of investigations into the use of reinforced concrete.

33. Aspects like aesthetics and the environmental performance of vaulted spaces were not mentioned among the reasons for the relevance of vaults to the Cuban context, and those reasons that were given were based more in observation than in systematic testing. In fact, later reports criticized brick vaults for their lack of insulation and waterproofing. See “Construcciones esco- lares,” *Arquitectura Cubana*, no. 333 (1965): 4–27.

34. In addition to nationalization, there was a transition from small-scale to large-scale production. Small farmers’ land was concentrated into cooperatives or large state farms. Artisans abandoned their small workshops to become part of large “consolidated” industries. In the case of construction, small artisan production workshops were replaced by large industrialized production plants. This was reflected in 1963 reports about the construction in Cuba. See International Union of Architects, *Cuba*, 41.

35. “La técnica, conocida de muchos siglos, solo lo era por tradición, perdiéndose mucha veces secretos de la misma al discontínuarse y sustituirse por métodos más prácticos y menos nobles. Nuestro interés de utilizar todo el personal y todos los métodos, así como el encontrar todas las razones históricas de su razón de ser, nos llevó a investigar la técnica artesanal de ladrillo y rastra, techo y entresuelo.” Ministerio de la Construcción, *Cerámica convencional*, 3. Unless otherwise noted, all translations are our own.

36. “El personal de investigación, al mismo tiempo que hacía el experimento, capacitaba al grupo de las propias obras.” Ministerio de la Construcción, 3.

37. “Todos los trabajos se ejecutaron con cerchas simples de madera, deslizándose primero y después con cerchas intermedias e hilos y finalmente al aire.” Ministerio de la Construcción, 3. In the construction of thin-tile vaults, Cubans used formwork systems that were very similar to the ones used in Spain, employing wood frames, strings, and wedges for centering and decentering. On the tools and methods used in Spain, see Luis Moya Blanco, *Bóvedas tabicadas* (Madrid: Ministerio de Fomento, 1947); Ángel Trufo i Rusiñol et al., *Construcción de bóvedas tabicadas* (Madrid: Instituto Juan de Herrera, Escuela Técnica Superior de Arquitectura, 2004).


39. Cuban brick production, based primarily in the central and western parts of the island, enjoyed a good reputation among architects and engineers. As architect Samuel Rolando stated: “I repeatedly called within the Ministry of Construction for the use of fired ceramics as it is essential to produce high-quality housing and buildings. . . . It was not only about vaults and domes, but also about walls, floors, and window frames, made traditionally or prefabricated.” Rolando, interview.

40. The fast-setting mortar used in construction of the thin-tile vaults was plaster of Paris mixed with cement in a 3:1 ratio. Mortar for the additional thin-tile layers was made of cement and sand in a 1:3 or 1:2 ratio. The mortar of the exterior finishing of the vaults was often made up of cement and lime to seal the vaults to prevent water infiltration. See Ministerio de la Construcción, *Cerámica convencional*, 15. Tiles and bricks were also used in reinforced shells and slabs, departing from the traditional method of vault construction in Cuba, as outlined in the MICONS publication *Cerámica armonada*. Only two reinforcement examples are mentioned in *Cerámica convencional*. One is a flat-slab construction where ceramic served as a mold for reinforced concrete slabs, and where the use of lightweight hollow ceramic facilitated installation of prefabricated reinforced brick panels. The other is simply a brief reference to the use of reeds for reinforcement of ceramic, without further elaboration, tables, or drawings. See Ministerio de la Construcción, *Cerámica convencional*, 2.

41. Analyses of the load tests focused on three different issues: resistance, breakage or cracks, and collapse. The results were modeled and registered by MICONS architects. Most of the repeated load tests were conducted on small-span barrel vaults. See Ministerio de la Construcción, *Cerámica convencional*, 43–45.

42. In the structural analysis of a vault, the team used three equations: chord and point of a circle; total load for a 1-meter strip of the vault; and the Goldenhorn equation for the minimum thickness of the vault. The Goldenhorn equation comes from the work of Argentine engineer Simon Goldenhorn. See Simon Goldenhorn, *Elementos de resistencia de materiales* (Buenos Aires: S. Amorrortu e Hijos, 1960). For the equations, see Ministerio de la Construcción, *Cerámica convencional*, 43–45.

43. One might imagine that the relationship between the formwork used and the span of the vault is rather clear: the narrower the span, the less formwork needed. However, in our study of the construction and recommendations arising from the experiments in the courtyard, we did not find such linear
correlation. The formwork used has more to do with the nature of the geometry, the vault's single or double curvature, than with the size of the span.

44. Ministerio de la Construcción, Cerámica convencional, 39.

45. Each of the vaults had a parabolic section with curvature determined by a span-to-height ratio of 1:5. The tables provided the vertices of the catenary section based on the desired span (3 meters, 3.5 meters, 4 meters, and so on).

46. For example, knowing that the main span for a rectangular room in a rural or urban house is 3 to 4 meters, one can reasonably infer that a barrel vault over such a space would feature either one layer of brick and one of tile or three layers of tile. Other MICONS publications confirm the use of the table over such a space in the luxurious private housing developments of prerevolutionary Cuba. See MINOP, “La arquitectura educacional de los sesenta en Cuba,” 8.

47. Large vaults remained standing in the MICONS courtyard for some time: later images show that the 15-meter sail vaults were converted into a big room that was annexed to the ministry's building. See D’Acosta, “La investigación y el desarrollo técnico,” 52.

48. Ministerio de la Construcción, Cerámica convencional, 40.

49. Loomis, Revolution of Forms, 33; Vittorio Garatti, “Prefiguración de futuro,” in Paradiso, Las Escuelas Nacionales de Arte de La Habana, 87.

50. Ministerio de la Construcción, Cerámica convencional, 38.

51. For example, in 1961 Frank Martínez worked within MICONS to develop a prototype for a circular market building made of modular components that would then be built in several locations across Cuba. Some of these markets were realized as only half circles due to space or budget constraints, while others were finished as full circles with open courtyards at their centers. Zar- doya Loureda, “La arquitectura educacional de los sesenta en Cuba,” 8.

52. Hernández and Zardoya Loureda, “Las ‘Casas de Pastorita’ en La Habana.”

53. Load-bearing walls, beams, and prefabricated slab panels served as structural elements. The study examined the composition and articulation of these structural elements, the details of their connections, and their methods of production. It also addressed the general design of the apartments, emphasizing the openness of their plans and highlighting living spaces, service areas, and furniture. Ministerio de la Construcción, Viviendas urbanas.

54. Ministerio de la Construcción, 32–42.

55. Ministerio de la Construcción, 71.

56. The fifth building used indoor service spaces and thus created added costs for plumbing fixtures, but the sixth avoided these costs, and MICONS adopted the design as a prototype for housing projects throughout Cuba. Urban housing with thin-tile vaults offered key advantages, including the use of bricks rather than more expensive concrete and the facilitation of drainage in the rainy Cuban climate. Each housing block included a staircase with a permeable façade that led to two apartments on each level. Each apartment consisted of a three-bay unit with a living area, service area, and sleeping area.

57. Ciudad de la Construcción, located in the south of Havana, was imagined to host 21,424 inhabitants in conditions similar to, if not better than, those found in the luxurious private housing developments that were built in Cuba before the revolution. Quintana’s ambitious plans included both single-story semidetached houses and multistory apartment buildings, with educational facilities, sports fields, and service zones. The planners and architects believed that public housing programs could offer the same for everyone, and their description of the project referred to the International Union of Architects’ 1955 declaration about housing being a right. The early description of the project in 1960 boasted about the amount of rebuilt open area surrounding the housing; 90 percent of the land was devoted to parks, playgrounds, and public areas, surpassing the 87 percent average for open space in the luxurious private housing developments of prerevolutionary Cuba. See MINOP, “La Ciudad de la Construcción,” Arquitectura Cuba, no. 327 (1960), 415–19.

58. Samuel Rolando was the site architect for this project, working for Quintana. He recalls that “before starting with the construction using the original plans, Ernesto (Che) Guevara asked for an immediate meeting with Quintana to discuss reducing both the areas and the costs and increasing the number of apartments. Quintana and his design team had to redesign the units; they introduced the vaults in the design of many buildings.” Rolando, interview.

59. Part of the Alamar area was later designated as a residential zone for foreign experts and engineers taking part in exchange programs with Cuba, hence the popular name of the zone: Houses of the Russians (Casas de los Rusos). The houses also served as student residences in the early 1970s as part of a university branch of Polytechnic José Antonio Echeverría (CUJAE) in Alamar. Students of engineering and architecture, including one of the authors of this article, had a curriculum that included practical work in the new form of collective self-help housing represented by the microbrigadas movement. In the late 1990s and early 2000s, the vaulted individual houses served as temporary accommodations for those on the waiting list for housing in the larger apartment blocks in the area.

60. The building of these vaults in Alamar’s two houses was justified as a way to eliminate the load-bearing walls, “so the vault that reaches the ground integrates the ceiling and the wall.” The summarized advantages and conditions for the success of this way of building were “the availability of labor, the minimum use of wood in the shuttering, the prefabricated mold, the savings in cements, and the eliminated use of steel.” Ministerio de la Construcción, Viviendas rurales (Havana: Dirección de Investigaciones Técnicas, Ministerio de la Construcción, June 1964), 105, 106.

61. The number of schools doubled in Cuba from 1957 to 1964. In addition to the conventional primary and secondary education program, Cuba introduced many other programs, including preschool, preuniversity, and vocational training, as well as childcare centers called Círculo Infantil, which were intended to help women by reducing the time they needed for maternity leave, maximizing their working time, and enabling them to participate in public work. See Zardoya Loureda, “La arquitectura educacional de los sesenta en Cuba.”

62. Omóteros is mentioned in Ministerio de la Construcción, Cerámica convencional, 83, but we were unable to find any further information about her life or work.

63. Primary education in Cuba consists of preschool followed by six grades, so the number seven formed the base of the modular system.

64. “Construcciones escolares.”

65. Ministerio de la Construcción, Cerámica convencional, 83. The architect could be Jorge Dorta-Duque, who was assigned by Fidel Castro to the program Changing Quarteles into Educational Cities (Convertir Cuarteles en Escuelas), but Dorta-Duque left the country after a short period of time. See Francisco Dorta-Duque, “Retoño de vieja amistad” (letter to the editor), El Nacional, 9 Nov. 2010, https://elnacional.com.do/cartas-de-los-lectores-991 (accessed 6 June 2019).


67. “Construcciones escolares.”

68. International Union of Architects, Cuba; Zardoya Loureda, “La arquitectura educacional de los sesenta en Cuba.”


70. Rebellón, interview.

71. Scholars such as Segre and Coyula associate the adoption of the Soviet model of prefabrication with the destruction caused by Hurricane Flora in 1963, which led the government of the Soviet Union to offer Cuba a prefabrication plant. See Segre, “Los años 60 y el Congreso de la UIA,” 33; Coyula, “La lección de Alamar,” 59. However, prefabrication was not merely imported from the Soviet Union; the use of prefabricated building materials developed in Cuba before, during, and after the establishment of the Soviet plant.
73. The particular system of precast concrete beams and clay-tile arched units with which tradicional mejorado is associated was known by the trade name PEPSA. Zardoya Loureda, “La arquitectura educacional de los sesenta en Cuba.”
74. “Viviendas experimentales de la Reforma Urbana (no incluye otros planes gubernamentales) de sistema convencional y tradicional con semiprefabricado, que constituyen el tradicional mejorado.” Ministerio de la Construcción, Viviendas urbanas, 65.
75. “Discurso del Dr. Fidel Castro en la clausura del VII Congreso de la UIA,” Arquitectura Cuba, no. 331 (1964), 44.
78. International Union of Architects, Cuba, 100.
81. “Estas condiciones económicas y técnicas plantean un reto histórico a los arquitectos: resolver funcional y estéticamente una nueva realidad técnica y social y crear un nuevo lenguaje arquitectónico y humano para la época en que el arquitecto por primera vez entrega su obra al disfrute de toda la sociedad.” International Union of Architects, 86.
82. D’Acosta, “La investigación y el desarrollo técnico.”
83. Toraya, 500 años de construcciones en Cuba, 283; Segre, Arquitectura y urbanismo de la revolución cubana, 30–31.
84. Both Segre and Toraya describe the creation of the Center of Technical Investigation as a first attempt by MICONS to industrialize construction in Cuba, without any mention of the center’s work on vaults and reinforced ceramics. See Segre, Arquitectura y urbanismo de la revolución cubana, 254; Toraya, 500 años de construcciones en Cuba, 284.
85. For reviews concerning the low quality of the housing built in the 1990s, see Dania González Couret, “Medio siglo de vivienda social en Cuba,” Revista INVI 24, no. 67 (2009), 87; Mario Coyula, “El derecho a la vivienda: Una meta elusiva,” Temas 58 (June 2009), 26.
87. The school’s thin-tile program started with a workshop convened in 2000 by builders from Extremadura (Spain) and Havana, which stimulated renewed interest in thin-tile vaulting and led to new vaulting projects for buildings such as the Orthodox and Russian churches in the Old City of Havana. See M. Wesam Al Asali, “Tools and Technology in Traditional Architecture: A Study of Thin Tile Vaulting” (master’s thesis, University of Cambridge, 2016); Rodríguez Sanchez Pedro, interview by M. Wesam Al Asali, Nov. 2018.