**Candela Isler Müther**

Positions on Shell Construction

# Candela
# Isler
# Müther
## Positions on Shell Construction

Edited by Matthias Beckh, Juan Ignacio del Cueto Ruiz-Funes,
Matthias Ludwig, Andreas Schätzke and Rainer Schützeichel

Birkhäuser
Basel

# Contents

# Introduction

In architecture, the heyday of concrete shell construction began in the years after World War II. Already during the first decades of the twentieth century, engineers such as Robert Maillart (1872–1940), Eugène Freyssinet (1879–1962), Franz Dischinger (1887–1953), Ulrich Finsterwalder (1897–1988), Eduardo Torroja (1899–1961), and Giorgio Baroni (1907–1968) had contributed significantly to its development by enhancing knowledge on the efficient usage of reinforced concrete as well as on the structural behavior of thin concrete shells. The full structural and artistic capacity of these structures, however, only unfolded from the late 1940s onward, made possible inter alia by the breakthrough of new methods and developments such as, and certainly not least, prestressed concrete. During the following roughly three decades, technically advanced structures of sensational expressiveness were created worldwide. The design and space-shaping possibilities that shell buildings offered met the demands and the spirit of the time. Not only did a large number of civil engineers and architects contribute to this, but also an array of clients from industry as well as from the public sector, not forgetting publicists, curators, and architecture critics all around the globe.

In this book, three protagonists of shell construction are treated as examples for the respective building production of this time: the architect Félix Candela (1910–1997) and two engineers, Heinz Isler (1926–2009) and Ulrich Müther (1934–2007). Their work unfolded against the background of different political, socio-economic, and cultural conditions. Nevertheless, they were engaged in a lively professional exchange across the boundaries of political systems, which on the one hand took place via personal networks. On the other hand, organizations such as the International Association for Shell Structures (IASS, now International Association for Shell and Spatial Structures), founded in 1959 by Eduardo Torroja, triggered an international exchange of knowledge. Regardless of their mutual influences and their common field of activity in general, though, the professional work of Candela, Isler, and Müther is also characterized by remarkable differences: while Candela, in Mexico and beyond, became the undisputed master of elegant shells, which he mostly realized as hyperbolic paraboloids (hypars) in public and industrial buildings, Isler, in Switzerland, positioned himself successfully as an entrepreneurial engineer, particularly with his standardized system of industrial shells that was optimized in both planning and construction, although he also gained a significant reputation as an expert for the design of free-form shells. Müther, for his part, in East Germany, was able to achieve a monopoly position

under the conditions of the socialist planned economy, both in the design, as well as in the construction and execution, of shell buildings by the company he managed, which for a large part of the time existed as a publicly owned enterprise.

In the past decades, significant historiographical contributions have already been made regarding Félix Candela, Heinz Isler, and Ulrich Müther. Numerous books have been published, essays have been written, and exhibitions have introduced their works to a broader public—sometimes in a critical scientific, sometimes in an affirmative manner. This book is, therefore, not intended to be another (three-part) monograph. Instead, it grew out of current research and is primarily based on archival sources that to a considerable extent were accessed for the very first time. The contributions in this volume, therefore, shed new light on commonly known themes in the works of Candela, Isler, and Müther, and they also bring to the fore overlooked or—up to now—only superficially addressed topics. They analyze buildings and projects of the three protagonists against the background of the developments in architecture and engineering of their time, and they deal with mutual influences, similarities, and differences in their form-finding and design processes as well as in construction and execution. Furthermore, questions of reception are addressed alongside the problem of preservation and an adequate current use of the now historic shell structures.

The book is the result of a collaboration between three scientific institutions: the Facultad de Arquitectura de la Universidad Nacional Autónoma de México (FA-UNAM, Faculty of Architecture at the National Autonomous University of Mexico), the Institute for the History and Theory of Architecture (gta) and the Chair of Structural Design at the Swiss Federal Institute of Technology (ETH) Zurich, and the Hochschule Wismar – University of Applied Sciences, Technology, Business and Design. In particular, it brings together the results of a series of international symposia that we have jointly organized, beginning with the first *Candela Isler Müther International Symposium: Concrete Shells in Mexico, Switzerland and Germany* (CIMIS), which took place in Mexico City in November 2018.

All three universities house archives without which our research would not have been possible: the Archivo de Arquitectos Mexicanos (AAM, Archive of Mexican Architects) at FA-UNAM holds a part of the estate of Félix Candela as well as bequests of important architects with whom he cooperated, such as Enrique de la Mora, Juan Antonio Tonda, and Alberto González Pozo; the posthumous papers of Heinz Isler are kept in the gta Archives at ETH Zurich; the estate of Ulrich Müther is accessible in the Müther Archive at Hochschule Wismar, where it laid the foundation stone for the Baukunstarchiv Mecklenburg-Vorpommern (Architecture Archives of Mecklenburg-Western Pomerania). The bequests of Isler and Müther have both only recently been catalogued and are now open for scientific use. This material contributes decisively to this critical comparative study on the works of Candela, Isler, and Müther. The editors hope that these fresh findings, which are presented here for the first time, will provide new insights and trigger further research.

Matthias Beckh
Juan Ignacio del Cueto Ruiz-Funes
Matthias Ludwig
Andreas Schätzke
Rainer Schützeichel

# Three Cultures and Ways of Making Reinforced Concrete Shells

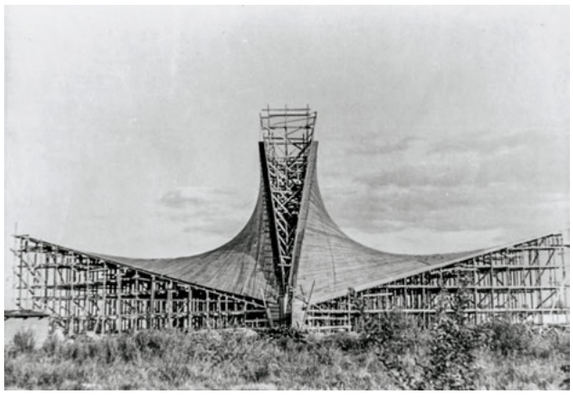
JUAN GERARDO OLIVA SALINAS

The latter period of a century of great transformations and contributions in the art of designing and building reinforced concrete shells is covered, between 1949 and 2009. Félix Candela (Madrid, Spain, 1910–Durham, USA, 1997), Heinz Isler (Zollikon, Switzerland, 1926–Bern, Switzerland, 2009), and Ulrich Müther (Binz, Germany, 1934–Binz, Germany, 2007) are three protagonists of this interesting era.

An enthusiastic research group on the study and development of reinforced concrete shells focuses on the projects and constructions realized by these three outstanding builders. By meeting and exchanging the information and knowledge they have on the subject, they combined their efforts to collect and disseminate the legacy of reinforced concrete shells that these three important characters bequeathed us. The reader should consider that during this period, other important builders also designed and constructed reinforced concrete shells, among whom the following stand out: Pier Luigi Nervi (1891–1979), Ove Arup (1895–1988), Eduardo Torroja (1899–1961), and Nicolas Esquillan (1902–1989). This essay is focused exclusively on how concrete shells by Candela, Isler, and Müther were made and on discussing the form-finding and construction procedures followed by each one of them.

## SHELLS AND INFLUENCES LINKING CANDELA, ISLER, AND MÜTHER

Through the design and construction of novel reinforced concrete shells, Félix Candela, Heinz Isler, and Ulrich Müther made important contributions to architecture and engineering. The main works of these three shell pioneers were realized in different countries: Mexico, Switzerland, and East Germany, respectively. However, the three builders made significant works in other countries as well. Candela, in addition to demonstrating his creative capacity as an architect, made important contributions to the engineering, geometry, and structural calculation of shells. He designed many outstanding and unique surfaces with double inverse curvature through the development of his admirable hyperbolic paraboloid surfaces. For their parts, Müther and Isler, in addition to demonstrating the masterful handling of mechanical calculations as civil engineers, made important contributions to the conception, design, and control of the architectural form. The three shell builders applied different procedures to determine the shapes of their structures and to construct them, but with common objectives: they all looked for structures of high efficiency with the



1 Enrique de la Mora and Félix Candela, San José Obrero church, Monterrey, 1959: view of the construction site


2 Logo of the PGH Bau Binz, the specialist building cooperative run by Ulrich Müther, ca. 1968

lowest environmental impact and where strength is achieved through form.

Candela's reinforced concrete shells were one of the sources of inspiration and motivation for both Isler and Müther to become interested in the design and construction of these unique structures. The cover of a book showing the restaurant Los Manantiales in Xochimilco, Mexico City, which Isler saw in the early 1960s, led to his great interest in thin concrete shells that were only 4 centimeters thick.[1] It was probably the book *Schalenbau* by the theoretical architect Jürgen Joedicke, published in 1962 in Stuttgart, the cover of which shows a color photograph of that restaurant.[2] Regarding the previously mentioned shell, "Isler considers that not only the minimal thickness of this shell but also its unmistakable wave form, with its perfect curves gives the structure its unique thrill."[3]

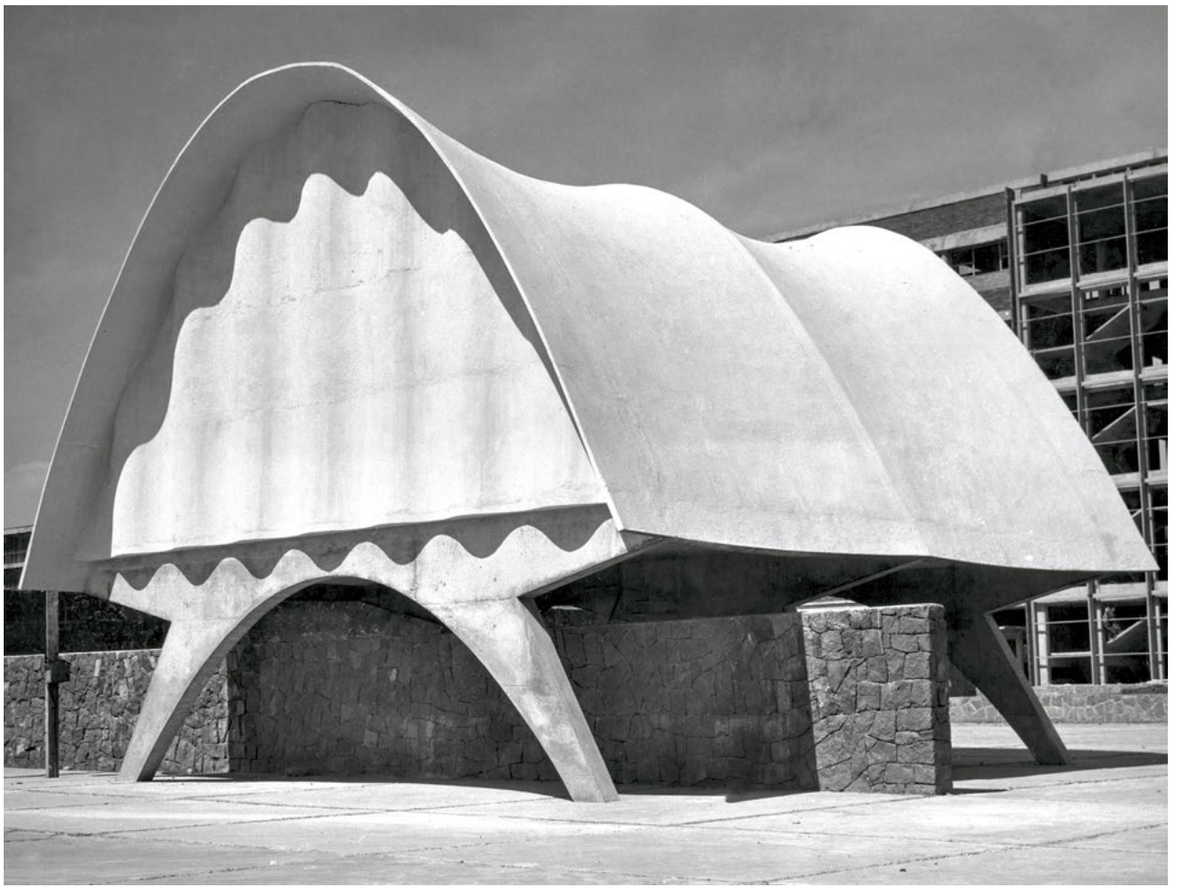
In 1963 Müther also ended up being influenced by the shells of Candela when he developed his diploma thesis at the Technische Universität Dresden. As part of his work, Müther had originally considered developing a cover for the Haus der Stahlwerker (Steelworkers' Home) in Binz based on barrel vaults. This deck would serve to cover a terrace that would function as a meeting room, as part of the extension to the vacation center of the steel and rolling mill VEB Rohrkombinat Stahl- und Walzwerk Riesa. However, the architect Ingo Schönrock, former fellow student and good friend of Müther, suggested that the roof deserved the design of a shell in the manner of Candela.[4] The above indicates that Candela's shells had already crossed the borders of many countries in the world. Subsequently, Müther designed a roof to cover an area of 200 square meters consisting of four hypars. This work constitutes his first reinforced concrete shell.

One more influence of Candela on Müther was the logo he used for his construction company PGH Bau Binz, which is based on the form of the San José Obrero church built in 1959 by Candela and Enrique de la Mora in Monterrey.[5] Undoubtedly, Müther recognized and admired the fascinating forms of Candela's shells. The silhouette of this shell was also engraved on the tombstone of Müther's grave.

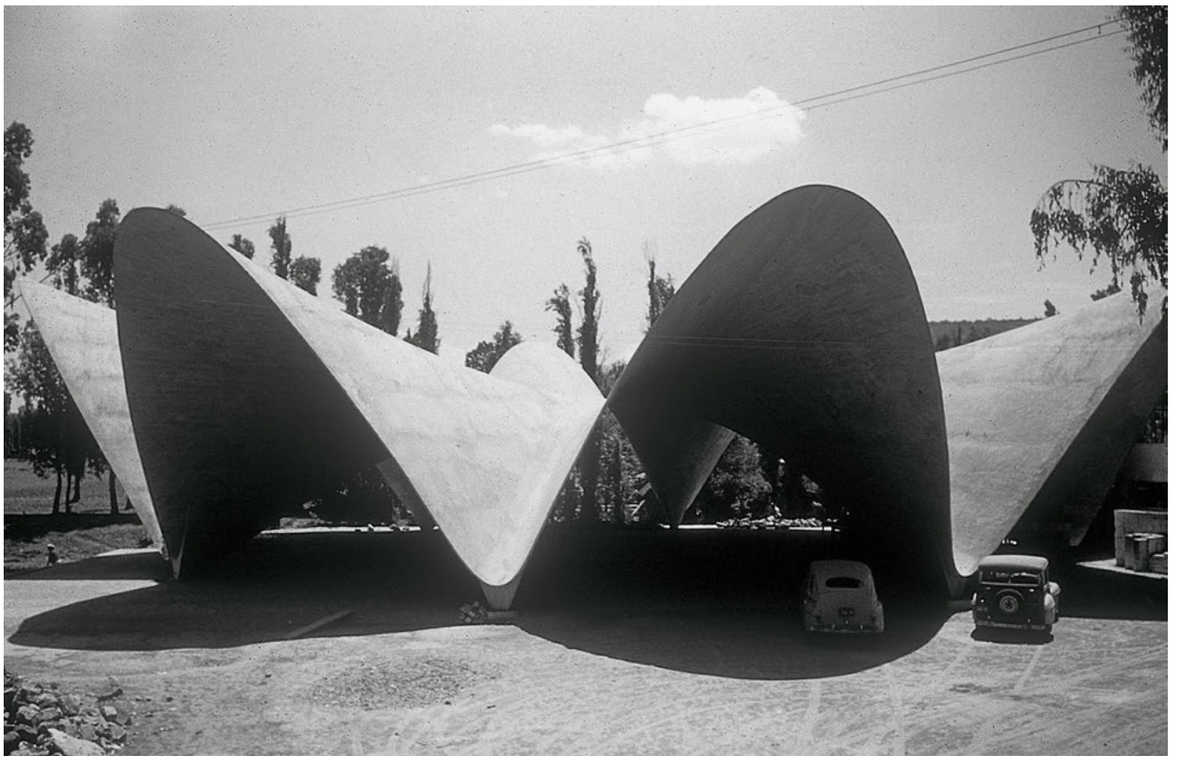
The author of this article had the opportunity to meet and talk with Candela and Isler and to attend presentations by both builders in Europe and in Mexico. With this background, he was able to verify that both characters shared common characteristics of simplicity, humility, and enthusiasm for innovating in the design and structural calculation of shells. Isler also enjoyed a very good sense of humor that characterized him and his wife, Maria. For both, a permanent smile was a typical feature that will always be associated with them. In 2003 Margarete Fuchs produced the documentary film *Für den Schwung sind Sie zuständig* (You are responsible for the Momentum) which she presented a couple of years later at the Faculty of Architecture of the Universidad Nacional Autónoma de México. The life and work of Ulrich Müther is described concisely in this film, in which he is portrayed as a simple, humble, and affable person.

## FÉLIX CANDELA'S SHELLS

Félix Candela was not the first to build reinforced concrete shells shaped like a hyperbolic paraboloid (HP), but he knew how to handle and control the shape of these surfaces in a masterly manner. By varying the proportions, adding, duplicating, or sectioning HP surfaces, Candela adapted the shape to the spatial architectural requirements, thus generating structures with maximum mechanical efficiency and with a minimum of material. Beauty was an aspect that Candela emphasized in an impromptu presentation given during the closing ceremony of the international symposium *Weitgespannte Flächentragwerke* (Wide-span Surface Structures) held from May 14 to 18, 1979, at the Universität Stuttgart: "Let me finish by talking of one thing that always strikes me in this kind of meetings. Nobody speaks of beauty, perhaps because it cannot be measured and engineers have a professional deformation to deal only with the so-called facts. Therefore, there are a lot of serious talks about stresses in all



3 Jorge González Reyna and Félix Candela, Cosmic Rays Pavillion, Ciudad Universitaria, Mexico City, 1951



4 Joaquín Álvarez Ordóñez and Félix Candela, Los Manantiales restaurant, Xochimilco, Mexico City, 1958; photograph by Juan Guzmán

directions, concentrations of them and subsequent deformations, but poor beauty is always forgotten. We should remember, however, that a great part of the success of these structures is due to the fact that they are usually very beautiful [...]."[6]

Candela experienced two anecdotal events at the initiation of his interest in thin reinforced concrete shells: first, the rejection he suffered in his approach to Eduardo Torroja; and second, the rejection of the first article he sent for publication to the *Journal of the American Concrete Institute* in 1951. As a student, and when he was in the sixth year of his career as an architect at the Universidad Politécnica de Madrid, Candela visited the construction site of the Frontón Recoletos, a Basque pelota indoor court. There he found Eduardo Torroja and asked him to explain in general terms the mechanical behavior of the large vaults of his roof. His response was unkind, and Candela felt rejected and his feelings were hurt.[7] Subsequently, in 1951 he sent the *Journal of the American Concrete Institute* a manuscript entitled "Considerations Concerning the Design of Reinforced Concrete Structures." It was rejected, indicating that it was inappropriate for publication in the journal: "The principal reason was that it is argumentative and reveals no new data on which the reader might base or review his opinions of design methods."[8] Nevertheless, that same year Candela sent a new article to the same journal that was accepted and published.

Candela knew how to understand the socioeconomic context of Mexican society in the 1950s. Labor was extremely cheap, and this context allowed him to carry out constructive procedures that required many workers, whose low salaries did not impact on the final cost of the work previously agreed with the client. With an army of workers, he assembled the impressive wooden formwork, which ultimately turned out to be sculptural works that would be destroyed once the thin reinforced concrete membrane had been cast. The cost of wood was not excessive at the time, but certainly the amount of wood required had a negative impact on the care of natural resources that Candela and his two colleagues Müther and Isler sought to achieve with the execution of their shells.

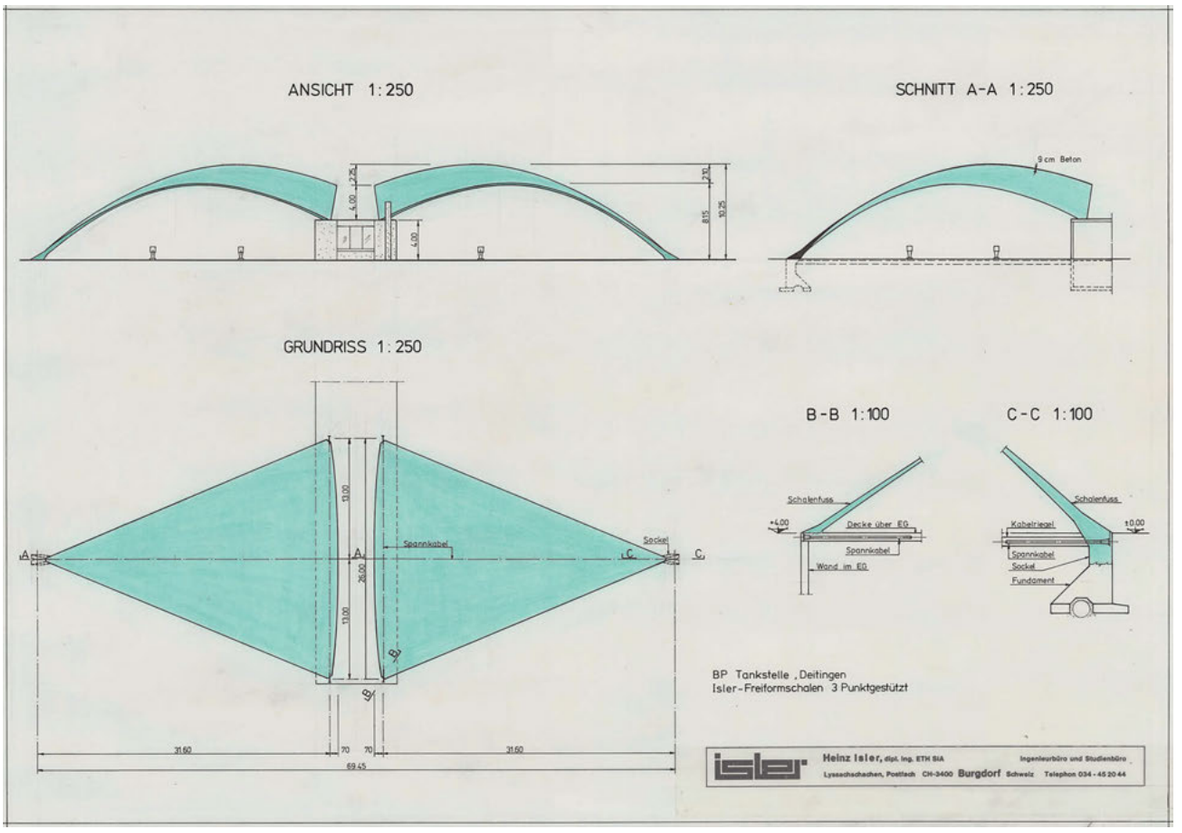
The workers paraded in long lines, transporting the concrete mixture to pour it over the wooden formwork and the reinforcing steel, which typically consisted of 3/8-inch (10-millimeter) steel bars spaced at 20 centimeters on center. Most of Candela's shells were only 4 centimeters thick. At the top half of the shells for the Cosmic Rays Pavilion designed by the architect Jorge González Reyna in the Ciudad Universitaria in Mexico City in 1951, Candela successfully achieved a minimum thickness of 1.5 centimeters.

The geometric and mechanical calculations of Candela started from the simple equation for a hyperbolic paraboloid surface in relation to a Cartesian coordinate system with three dimensions: $z = kxy$. As an architecture student, the author of this article recalls comments from professors working with Candela who affirmed the disbelief of many structural engineers in the face of the simplicity of Candela's equations. Furthermore, during his studies at the Universität Stuttgart in the late 1970s, the author was a student of Jürgen Joedicke. In his class on architecture theory, Joedicke described Candela's shell for the Los Manantiales restaurant, highlighting its perfect integration into the amazing urban landscape in Xochimilco, right next to one of the beautiful canals that make up the rainforest network of this unique and fascinating place. Years later, during a conference in Mexico City, Candela explained to the audience in a very colloquial way that in his Xochimilco shell, he had had the challenge to build a new cover as quickly and cheaply as possible to replace the former one, which had burned down. The owner of the restaurant was an acquaintance of his. Candela's beautiful combination of eight HP surfaces was the right solution in this particular case. His modesty was frequently manifested in his person and manner of behavior. This Candela project is one of the most beautiful examples of his shells, and its shape was repeated, built with fiberglass-reinforced concrete in West Germany by Jörg Schlaich and with reinforced concrete by Ulrich Müther in East Germany. This form would also be repeated in South America, in other countries of the world, and in the Ciutat de les Arts i les Ciències (City of Arts and Sciences) in Valencia by Candela himself shortly before his death.

Félix Candela did not have the support of a university as a framework to carry out experimental tests of his shells. However, in 1949 he built an experimental shell with a catenary directrix. Candela would go on to realize more than 1,400 projects over the next two decades and build about 900 shells. However, when he built the large metal roof of the Palacio de los Deportes (Sports Palace) for the 1968 Olympic Games in Mexico City, a scale model was constructed to analyze the mechanical behavior of the shell. This amazing roof is the last shell built by Candela in Mexico, in collaboration with Antonio Peyrí Maciá and Enrique Castañeda. The shell for the Palacio de los Deportes is the only one built with metal instead of reinforced concrete.

## HEINZ ISLER'S SHELLS

Heinz Isler designed shells with shapes that were determined through physical models, unlike Candela and Müther, whose shells adhered to precise mathematical formulas. Isler claimed that the mechanical calculations necessary to determine the forces and the forces acting on their shells were relatively simple and feasible to be done with simple manual calculations. In the 1970s a




5 Heinz Isler, motorway station Deitingen Süd, 1968, undated colored plan

boom in the use of computers began; however, Isler dispensed with them since he did not consider them necessary. "Isler considers that even the best computer calculation is no better than his formula by hand."[9]

In addition to defining the shape, Isler's physical models were also used to examine the mechanical behavior of his shells. Despite applying different design methods, Candela, Müther, and Isler sought to generate shells to resist the loads to which they would be subjected with a minimum of material, but with a maximum of mechanical efficiency, generating a minimum of stresses and deformations—what we now call sustainability, a term not used at that time.

Isler generated the surface of his thin shells, ensuring that the loads produced by their own weight were transmitted exclusively by compression. Analogous to the form-finding methods applied by Antoni Gaudí (1852–1926) and Frei Otto (1925–2015), Isler started from the principle of the hanging model that works exclusively in tension because of its own weight and which, once inverted, works exclusively in compression. The design of Isler's first bubble shells was inspired by the shape of the pillow on his bed. To determine the geometry, he built physical models in which he inflated a rubber membrane attached to a rectangular wooden edge. Isler rounded the shape of the four corners to avoid generating undesirable negative curvature. Now the entire surface was positively curved and worked exclusively in tension; therefore, the said geometry was suitable for a concrete shell working only under compression. The original models used by Isler to determine the shape of his bubble shells remained preserved for many years in the basement of his office.[10]

Isler carried out tests to measure the distribution of stresses in his models, and after many tests and geometric and mechanical reflections he came to verify that 90 percent of the weight of the roof arrived directly at the four corners of the bubble shells. Based on the foregoing, Isler concluded that he could build stable and safe shells by ensuring adequate support at the corners and using slender edge beams. With these experiments Isler opened great possibilities for architects and structural engineers to design shells with a great freedom in their facades, free of any unnecessary support elements. "Isler has never been formally trained as an architect, yet he has an eye for beauty and elegant form, which stems from his appreciation of nature and love of painting and sketching."[11]

Isler also experimented with free-form shells based on shapes determined by hanging membranes. He hung a membrane at points of support that simulated the position of the supports that the structure would have and allowed that membrane to deform naturally due to its own weight. In a public demonstration of this principle, in Stuttgart, in 1994, Isler hung a four-point membrane located in the same plane and carefully dipped it in a vessel containing polyester resin. The weight of the resin as well as that of the membrane itself

created a shape that again opened new possibilities of application to architects and shell designers. Other variants to determine the form that Isler experimented with were membranes saturated with resin that hung from a fixed point located toward the center of the membrane or membranes that hung in the garden during the winter and generated colorful and attractive natural shapes when frozen.[12]

## ULRICH MÜTHER'S SHELLS

Ulrich Müther's shells were not recognized for many years. In 2000 the Ahornblatt (Maple Leaf) restaurant, one of his most significant shells, located in Berlin, was destroyed. Despite what happened, the destruction of these shells led to Müther's work being recognized both in Germany and worldwide.

Most of Ulrich Müther's and several of Heinz Isler's shells were constructed with a concrete spraying process. Sometimes they combined this process with conventional tipped concrete, similar to the construction procedures applied by Candela. However, in the project that Müther developed in his diploma thesis to cover a terrace of the Haus der Stahlwerker, which became his first hypar shell, the constructive procedures applied were analogous to those used by Candela. The roof measures 14.20 × 14.20 meters and is 7 centimeters thick. It was built in 1964 and demolished in 2001.[13] To perform the mechanical calculations and so that they could be supervised as part of his thesis, Müther had to resort to the new Department of Theory and Construction of Surface Structures directed by Professor Reinhold Rabich at the Technische Universität Dresden. Rabich was a renowned theoretician who had already worked as an assistant to the engineer Franz Dischinger (1887–1953), who was also a renowned German shell builder. Once Müther finished the mechanical calculations, Rabich performed mechanical tests on a physical model at the Technische Universität Dresden, necessary to ensure the stability of the shell. Müther would devote another 30 years to the construction of shells after his first hypar in 1964.

Other significant works by Müther are the Seerose café in Potsdam (1980–1983, in collaboration with the architect Dieter Ahting) and the Teepott restaurant in Rostock-Warnemünde (1967/1968, in collaboration with the architects Erich Kaufmann, Carl-Heinz Pastor and Hans Fleischhauer), the forms of which were inspired by Candela's shells for Los Manantiales (1958, in collaboration with the architect Joaquín Álvarez Ordóñez) and the La Jacaranda nightclub in Acapulco (1956/1957, in collaboration with the architect Juan Sordo Madaleno), respectively.[14] In 1984 the Teepott was declared a protected monument. It remained empty for a long time and in 2002 it was restored and significantly modified. Müther presented the Teepott in 1969 in Madrid during the annual symposium of the International Association for Shell Structures.[15]

6 Dieter Ahting and Ulrich Müther, Seerose café, Potsdam, 1983

7 Erich Kaufmann, Carl-Heinz Pastor, Hans Fleischhauer, and Ulrich Müther, Teepott restaurant, Rostock-Warnemünde, 1968

8 Juan Sordo Madaleno and Félix Candela, La Jacaranda nightclub, Acapulco, 1957

## CONCLUSION

The vast majority of Félix Candela's and Ulrich Müther's shells were designed in collaboration with other architects who conceived the shells that these two builders would help to develop successfully. The only shell design that is attributed solely to Candela is the La Medalla Milagrosa church, built in 1954/1955 in Mexico City. Heinz Isler also built several shells in collaboration with other architects or construction companies. Candela's shells were on average 4 centimeters thick; Isler's shells, 8 to 10 centimeters; and Müther's shells, 7 centimeters. Laborers hand-pouring the concrete on the formwork of the shell was the procedure commonly used by Candela, while Isler and Müther used to apply the concrete mainly by pouring or through sprayed concrete procedures. Candela and Müther built mainly with masterly combinations of hyperbolic paraboloid surfaces, while Isler, although he occasionally utilized hypar surfaces, conceived and designed many of his shells with surfaces of positive curvature.

The differences in the design and construction among the three great builders of reinforced concrete shells previously described are not the whole story: there are exceptions that the reader should take into consideration. Despite these aforementioned differences, through the realization of their reinforced concrete shells, Félix Candela, Heinz Isler, and Ulrich Müther sought the conception, design, and construction of sustainable lightweight structures: high efficiency with the lowest environmental impact, care of natural resources, minimum quantity of building materials, strength achieved through the form, and low stresses that lead to low maintenance and long life.

References


*2. Internationales Symposium. Weitgespannte Flächentragwerke. 14. bis 18. Mai 1979, Stuttgart,* vol. 2, *Berichtsheft/Proceedings.* Stuttgart, 1979.

Cassinello, Pepa, ed. *Félix Candela: Centenario 2010, La conquista de la esbeltez / Centenary 2010, The Achievement of Slenderness.* Madrid, 2010.

Chilton, John. *Heinz Isler: The Engineer's Contribution to Contemporary Architecture.* London, 2000.

Del Cueto Ruiz-Funes, Juan Ignacio, ed. *Aquella primavera creadora ... cascarones de concreto armado en México / That Creative Spring ... Reinforced Concrete Shells in Mexico.* Mexico City, 2008.

Del Cueto Ruiz-Funes, Juan Ignacio, and Monique Lambie, eds. *Félix Candela, 1910–2010.* Madrid, 2010.

Faber, Colin. *Candela: The Shell Builder.* New York, 1963.

Fuchs, Margarete. *Für den Schwung sind Sie zuständig.* Documentary film, Germany, 2003.

Isler, Heinz. "Aplicaciones recientes de cascarones representativos," *Revista IMCYC* 5, no. 30 (1968): 41–68.

Joedicke, Jürgen. *Schalenbau: Konstruktion und Gestaltung,* with contributions by Walter Bauersfeld and Herbert Kupfer. Stuttgart, 1962.

Ludwig, Matthias, Johannes Liess, Asko Fromm, Andreas Schätzke, and Antje Diebermann. *Der Teepott in Rostock-Warnemünde,* edited by the Bundesingenieurkammer. Historische Wahrzeichen der Ingenieurbaukunst in Deutschland 23. Berlin, 2018.

Moreyra Garlock, Maria E., and David P. Billington. *Félix Candela: Engineer, Builder, Structural Artist.* New Haven/London, 2008.

Oliva Salinas, Juan Gerardo. "Ulrich Müther (1934–2007): El maestro constructor de la provincia de Rügen," *Anales del Instituto de Investigaciones Estéticas* 29, no. 90 (2007): 273–84.

Seeböck, Tanja. *Schwünge in Beton: Die Schalenbauten von Ulrich Müther.* Schwerin, 2016.



The author wishes to thank his colleagues Maria Garlock, David Billington, Pepa Cassinello, José Antonio Torroja, Tanja Seeböck, Matthias Ludwig, and John Chilton, who kindly presented him with five excellent books that compile the life and work of Félix Candela, Ulrich Müther, and Heinz Isler and whose content made it possible to compile the information contained in this essay. This study is partially sponsored by the General Issues Department for Academic Personnel DGAPA-UNAM, Program PAPIIT IG 400517.


1 See John Chilton, *Heinz Isler: The Engineer's Contribution to Contemporary Architecture* (London, 2000), 20.
2 Jürgen Joedicke, *Schalenbau: Konstruktion und Gestaltung,* with contributions by Walter Bauersfeld and Herbert Kupfer (Stuttgart, 1962). English edition: *Shell Architecture* (New York, 1963).
3 See Chilton, *Heinz Isler,* 20 (see note 1).
4 See Tanja Seeböck, *Schwünge in Beton: Die Schalenbauten von Ulrich Müther* (Schwerin, 2016), 77–78.
5 See Matthias Ludwig, Johannes Liess, Asko Fromm, Andreas Schätzke, and Antje Diebermann, *Der Teepott in Rostock-Warnemünde,* ed. Bundesingenieurkammer (Berlin, 2018), 42–43.
6 Félix Candela, "Remarks on the Stage of Development," in *2. Internationales Symposium. Weitgespannte Flächentragwerke, 14. bis 18. Mai 1979, Stuttgart,* vol. 2, *Berichtsheft / Proceedings* (Stuttgart, 1979), 14.
7 See Maria E. Moreyra Garlock and David P. Billington, *Félix Candela: Engineer, Builder, Structural Artist* (New Haven/London, 2008), 56.
8 Letter from Willam A. Maples, American Concrete Institute, to Félix Candela, April 13, 1951, in ibid., 70.
9 Chilton, *Heinz Isler,* 23 (see note 1).
10 See ibid., 33. The models are still preserved in the gta Archives at ETH Zurich.
11 Ibid., 156.
12 See ibid., 36–38.
13 See Seeböck, *Schwünge in Beton,* 312 (see note 4).
14 See Ludwig, Liess, Fromm, Schätzke, and Diebermann, *Der Teepott,* 13–14 and 48 (see note 5).
15 See ibid., 10.

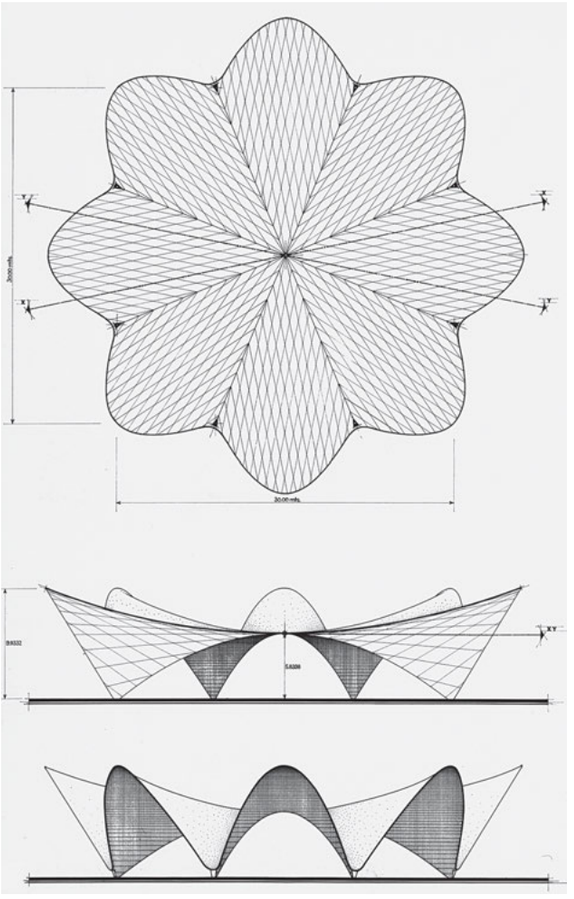
# Relations between Félix Candela, Heinz Isler, and Ulrich Müther

MATTHIAS LUDWIG

In January 2001 I was appointed as a professor for design at the Hochschule Wismar – University of Applied Sciences, Technology, Business and Design in the course of architectural studies. At that time, as a southern German, I did not know much about this region on the Baltic Sea except that there are beautiful beaches, numerous large brick churches enthroned above medieval Hanseatic cities, and that Caspar David Friedrich captured the wonderful atmosphere of the local landscape in his paintings. But there was something else that I remembered: in Mecklenburg–Western Pomerania there are shell structures made of thin reinforced concrete, which were planned and built by the East German civil engineer Ulrich Müther.

At the time of the Cold War, the public in West Germany knew hardly anything about these structures; only a few interested architects and engineers were aware of them. As a scientific staff member at the Institute for Building Construction, Chair 1, at Universität Stuttgart, I came across a volume of the Arcus: Architektur und Wissenschaft series on the work of Félix Candela.[1] Herrmann Rühle reports in it about the shell constructions of Ulrich Müther. A few years later, after the political change in Germany, this interest was stimulated again by Wilfried Dechau, who was editor-in-chief of *db: Deutsche Bauzeitung* at that time. Dechau was one of the first journalists to rediscover Müther and make him accessible to a wider public in the West German regions.[2] Especially his book *Kühne Solitäre*[3] and an exhibition catalogue on Heinz Isler's shell structures[4] inspired me to deal with the subject. Like Müther, Heinz Isler was at that time completely outside the focus of architecture enthusiasts, because the time of the great shell builders such as Eduardo Torroja or Félix Candela was long gone.[5]

In East Germany, Ulrich Müther's buildings eked out a miserable existence after the fall of the Berlin Wall and the insolvency of his construction company, with most buildings standing empty and quickly falling into disrepair. One did not see any engineering or architectural masterpieces in these structures, but only built gloomy memories of a Socialist Germany that nobody wanted to have anymore. The low point of this development can perhaps be seen in the demolition of the Ahornblatt restaurant in Berlin in 2000. It was precisely at this time that Müther founded his private company archive in the former KdF seaside resort of Prora.[6] In 2006 this situation took on a new dynamic: one of our students was working as a trainee in the planning office Müther Ingenieure in Binz at the time and arranged for the Müther archive to be transferred to the Hochschule Wismar. Ulrich Müther found that his office estate was in good



1 Joaquín Álvarez Ordóñez and Félix Candela, Los Manantiales restaurant, Xochimilco, Mexico City, 1958; from Colin Faber's book *Candela: The Shell Builder*, 1963

hands at the only architectural school in Mecklenburg–Western Pomerania. He died soon afterward in 2007. In the meantime, there have been quite a few searches in the archive for information on Müther's shell constructions. Publications about Ulrich Müther are accumulating, and buildings of the so-called Ostmoderne (Eastern modernism) are again in vogue.

## FÉLIX CANDELA: HYPERBOLIC PARABOLOID SHELLS

Félix Candela (1910–1997)
***Location:*** Spain, Mexico, USA | Architect (company: Cubiertas Ala S.A.) | ***Education:*** Escuela Técnica Superior de Arquitectura de Madrid, Real Academia de Bellas Artes de San Fernando | ***Shell type:*** hyperbolic paraboloid (barrel vault, spherical shell), some folded plate and conoid shells | ***Formwork:*** timber | ***Number of shells built:*** approximately 900, in Mexico, Guatemala, Venezuela, Colombia, and Cuba

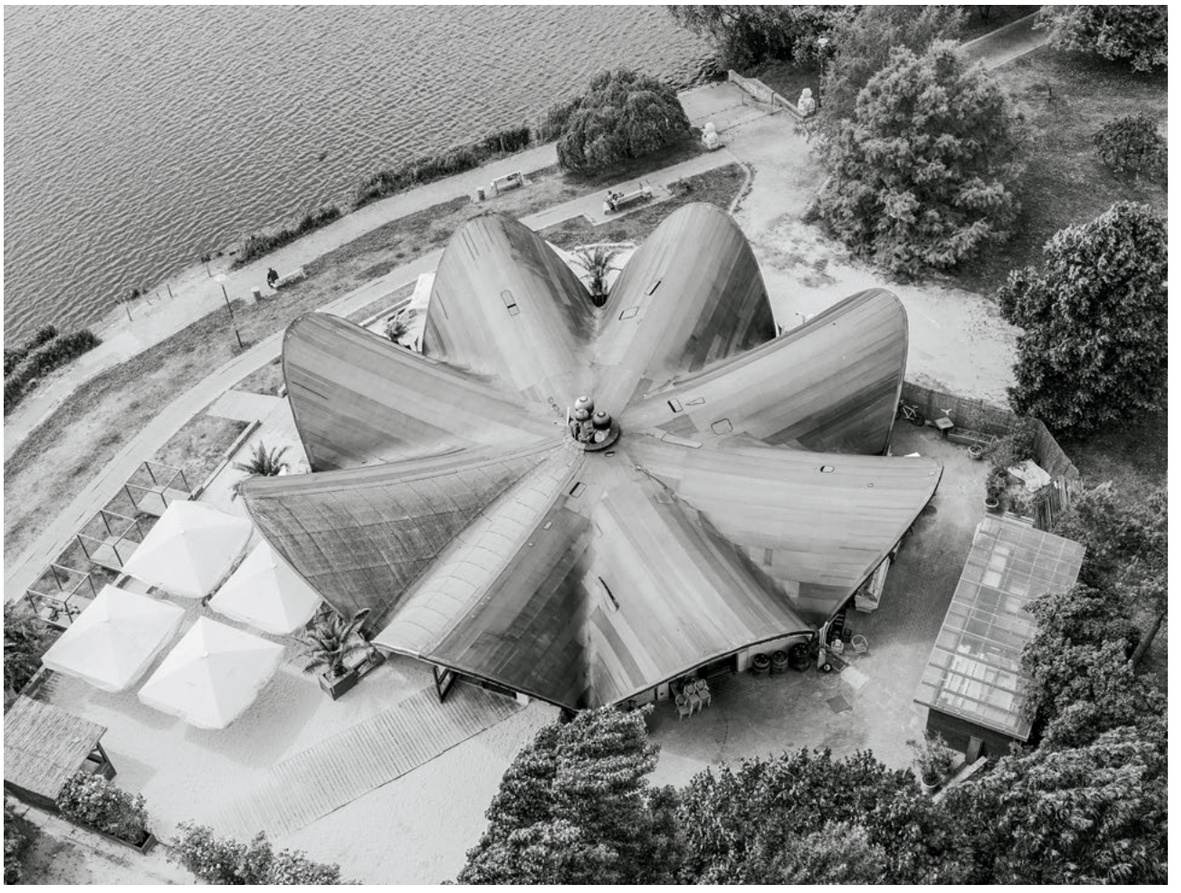
For his first shell constructions Ulrich Müther strongly referred to the Spanish-Mexican shell builder Félix Candela, although he probably never met him personally, even though both had attended conferences of the International Association for Shell and Spatial Structures (IASS). However, we know from interviews with contemporary witnesses that Müther had a book about Félix Candela on his bookshelf—in the GDR it was not easily available in bookstores.[7] In addition, his architect colleague Ingo Schönrock had enthusiastically reported to Müther a lecture given by Candela in July 1961 to a Bund Deutscher Architekten (Association of German Architects) group in the GDR and had published an essay on Candela's umbrella shells in the journal *Deutsche Architektur* in 1962.[8] Inspired by Candela's architecture, Müther realized his first hyperbolic paraboloid, the Haus der Stahlwerker (Steelworkers' Home) in Binz on Rügen island (1963/1964), while still a student at the Technische Universität Dresden (see the contribution by Andreas Schätzke in the present volume, fig. 8). The model for this was the Herdez warehouse roof in Mexico City (1957).

As a civil engineer, Müther was, against the background of his parents' construction company, very fond of the geometry of the hyperbolic paraboloid, since the formwork can be constructed comparatively easily by simple manual methods using straight shuttering boards. In addition, these thin concrete shells were a good answer to the GDR's economy of scarcity, because they saved on expensive cement and there was enough cheap labor, a situation very similar to that of Mexico. At a later date, Müther even visually documented his veneration of the Mexican master builder: the company logo of PGH Bau Binz (later VEB Spezialbetonbau Binz/Spezialbetonbau Rügen), used from the late 1960s onward, depicts the San José Obrero church in Monterrey (1959) and not, as one might assume, a ship's anchor or even an *M* for Müther.

## ULRICH MÜTHER: HYPERBOLIC PARABOLOID AND FREE-FORM SHELLS

Ulrich Müther (1934–2007)
***Location:*** Binz, GDR (until 1990)/Germany (since 1990) Civil engineer and builder (company: PGH Bau Binz/VEB Spezialbetonbau Binz/VEB Spezialbetonbau Rügen/Müther Spezialbetonbau GmbH) | ***Education:*** Fachschule für Bauwesen Neustrelitz, Technische Universität Dresden | ***Shell type:*** hyperbolic paraboloid and free-form | ***Formwork:*** timber, shaped hill, without | ***Number of shells built:*** 75 (including monuments, folded plates, cable net structures, and projects where he only did the concrete work), in Germany, Finland, Libya, Kuwait, and Cuba[9]

The connections between Müther and Candela are most obvious in two projects: the Los Manantiales restaurant in Xochimilco, Mexico City (1958), and the



2 Dieter Ahting and Ulrich Müther, Seerose café, Potsdam, 1983

riverside pavilion Seerose (Water Lily) in Potsdam (1982/1983), both consisting of eight hyperbolic paraboloid segments, so their formal similarity cannot be overlooked. Los Manantiales is 32.40 meters in diameter and 5.84 meters in height, with a shell thickness of 4 centimeters. The Seerose is much smaller: 23 meters in diameter, with a shell thickness of 6 centimeters. Of course, Müther's riverside pavilion is a reworking of Candela's design. Müther also made nearby water surfaces his own, as a reflecting pool typical of the modern age, and his Seerose also became, like Los Manantiales, a popular restaurant for city dwellers.

Other architects have also recognized the attractiveness of Candela's building: Jörg Schlaich experimented with this form at the Bundesgartenschau (Federal Garden Show) in Stuttgart in 1977. Candela's building, designed in collaboration with the architect Joaquín Álvarez Ordóñez, was one of the most published buildings at the time of its construction. Of course, despite the formal similarity of these buildings, there are many differences in the construction and manufacturing processes.

After all, almost 25 years lie between Los Manantiales and the Seerose. The form and geometry of Candela's building is undoubtedly more elegant than that of Müther's. And of course, the mild climate of Mexico City's plateau allows for more beautiful details on the shell and facade. But the Müther building, which was built in collaboration with the architect Dieter Ahting, has adopted the technological advances of its time: with just a few specialists, Müther was able to project the concrete onto the formwork using the so-called Torkret (shotcrete) method, while Candela had to do this laboriously with small buckets and a hundred workers.

## HEINZ ISLER: FREE-FORM SHELLS

Heinz Isler (1926–2009)
***Location:*** Burgdorf, Switzerland | Civil engineer and painter | ***Education:*** Eidgenössische Technische Hochschule (ETH) Zurich | ***Shell type:*** Free-form, partially hyperbolic paraboloid | ***Formwork:*** timber, inflated, shaped hills, without | ***Number of shells built:*** approximately 1,400, including projects in Switzerland, Germany, France, Austria, Saudi Arabia, and the United Kingdom

At the founding congress of the IASS in Madrid in 1959, the young Heinz Isler gave a groundbreaking lecture on the diversity of shell shapes.[10] He reported to the experts, among them Eduardo Torroja and Ove Arup, that mathematically or geometrically defined shells—

3 Dietrich Otto and Ulrich Müther, observation tower of the water rescue service, Binz, 1981

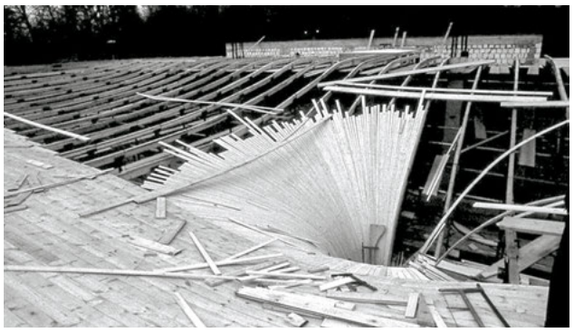
such as those designed by Félix Candela and also later by Ulrich Müther with their hyperbolic paraboloids—were neither statically favorable nor aesthetically satisfactory. Heinz Isler learned in just a few years (from 1953 to 1959), through observations of nature, how physical laws determine the natural form. During this time, he developed all the essential form-finding methods for so-called free-form shells: the membrane under pressure, for bubble shells; and the hanging cloth and so-called flow form, which was derived from the principles of the freely shaped hill.

His colleagues were skeptical at first, but Heinz Isler had a very intensive phase of building from 1960 to 1969. Hundreds of bubble shells—and parallel to them, edge-beamless free-form concrete shells—were built. The success of this serial production would prove him right. Later, in the 1970s, he also created a few prototypes, spherical houses, and, in collaboration with artists, sculptures and monuments. For the smaller shells, Isler tried out materials such as glass fiber reinforced plastics (GRP), and for modeling or for experimental temporary forms, plaster and ice in addition to concrete.

Ulrich Müther and Heinz Isler first met in 1966 at a building exhibition in Budapest.[11] The connection between the two shell makers lasted for quite a long time: they later met in Burgdorf at Isler's office and in Binz to hold technical discussions, but they also got along very well privately. This can be seen from the fact that Heinz Isler was among the guests at the opening of the company archives in Prora on June 24, 2000, while Jörg Schlaich, among others, gave a lecture.

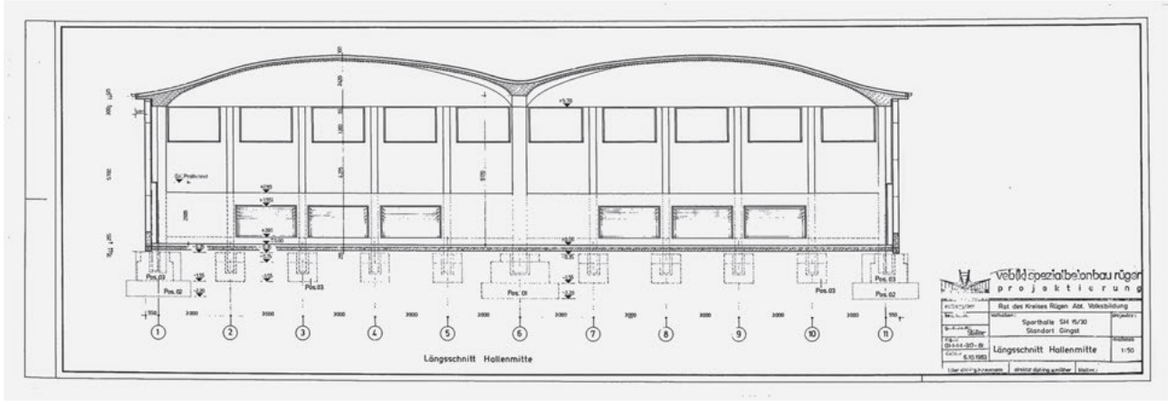
A closer look at the two lifeguard rescue towers in Binz from 1975 and 1981 suggests that Ulrich Müther was inspired by Isler's "freely formed hill" principle. This becomes clear when examining the manufacturing process of the two towers. The concrete negative mold of the two geometrically exactly identical halves of the shell was molded on a sand mound. The production of this free-form with a wooden formwork would have been very costly, especially at the strongly curved corners, where one would not have been able to cope with a straight plank formwork as used for hypar shells.

When the two beach towers were built in Binz, the young architect Dietrich Otto was working in Müther's company and took on the role of architect or form-finder for some rather futuristic-looking projects. Space design was in the air in the 1960s and 1970s; many designs, such as Buckminster Fuller's Dymaxion House (the prototype for which he had already designed in 1927) or Matti Suuronen's Futuro House (1968), were more reminiscent of cars or airplanes than of down-to-earth architecture. Stanley Kubrick's film *2001: A Space Odyssey* (1968) was a style-influencing work. Perhaps Otto had also seen Angelo Mangiarotti's Cnosso lamp



4 Kurt Tauscher and Ulrich Müther, swimming pool in the Baabe leisure spa, Sellin, 1977: formwork for the roof

5 Harry Neumann and Ulrich Müther, sports hall, Gingst, 1985




6 Harry Neumann and Ulrich Müther, sports hall, Gingst: longitudinal section; drawing by VEB Spezialbetonbau Rügen, 1983

manufactured by Artemide, which was produced from 1968 onward. If you put two of these lights together into a compact volume, you get a model of the beach towers, so to speak.

A few years earlier, in 1973, Dietrich Otto had designed a bus shelter in Buschvitz on the island of Rügen. This free-form shell, created as an MMM project, is very reminiscent of the so-called Kugelhäuser (spherical buildings) by Heinz Isler.[12] In the bequest of Heinz Isler in the gta Archives at ETH Zurich there are drawings of a similar bus shelter from 1977, a preliminary product of the concrete spherical shelters that was never realized.

Müther's bus-shelter project was produced with a so-called formless process. A kind of wire basket made of reinforcing steel was formed in the workshop of Spezialbetonbau Binz and covered with fine-mesh wire mesh. The concrete was then applied on site, using the Torkret shotcrete method, and finally smoothed by hand. Both Müther and Isler used porthole-shaped windows on the spherical houses. Isler further developed this type several times in 1977. For example, balloon houses built in Iran were designed with the architect Justus Dahinden. The special feature of these is the use of an inflated balloon as formwork. Three layers were applied to the balloon: first plaster with wire mesh inlay, then polyurethane (PU) foam, and finally concrete on the outside. The PU-foam was to provide thermal insulation for the building.

In this context, a building with spherical geometry by Félix Candela is also worth mentioning: La Jacaranda cabaret in Juárez, Mexico City, built in 1954 in collaboration with the architect Max Borges, Jr. This spherical segment shell with a diameter of 22.50 meters is one of the few that does not use the hypar geometry that distinguishes almost all of Candela's work. The spherical shape desired by the architect is at the expense of a formwork that is easy to make, as all the boards have to be bent into shape.

Ulrich Müther once said of himself that he did not like to experiment, but rather wanted to build solidly calculable projects, as he usually had the responsibility for the whole project in almost turnkey construction. An exception is the swimming pool roofing in the Erholungsheim (leisure spa) Baabe in Sellin (1977). Müther and his employees experimented with a rubber membrane clamped in a frame. This was loaded with small tile pieces and thus brought into a hanging form. As a process of finding the shape, this is not dissimilar to Isler's membrane under pressure or hanging fabric, in principle a combination of both: Isler's membrane under pressure was pressed upward in a frame with air pressure, while the hanging fabric is suspended, attached at three or four points.

Müther's shell shape for the swimming pool roof was thus developed by a membrane clamped in a frame and hanging downward. In order to be able to drain rainwa-