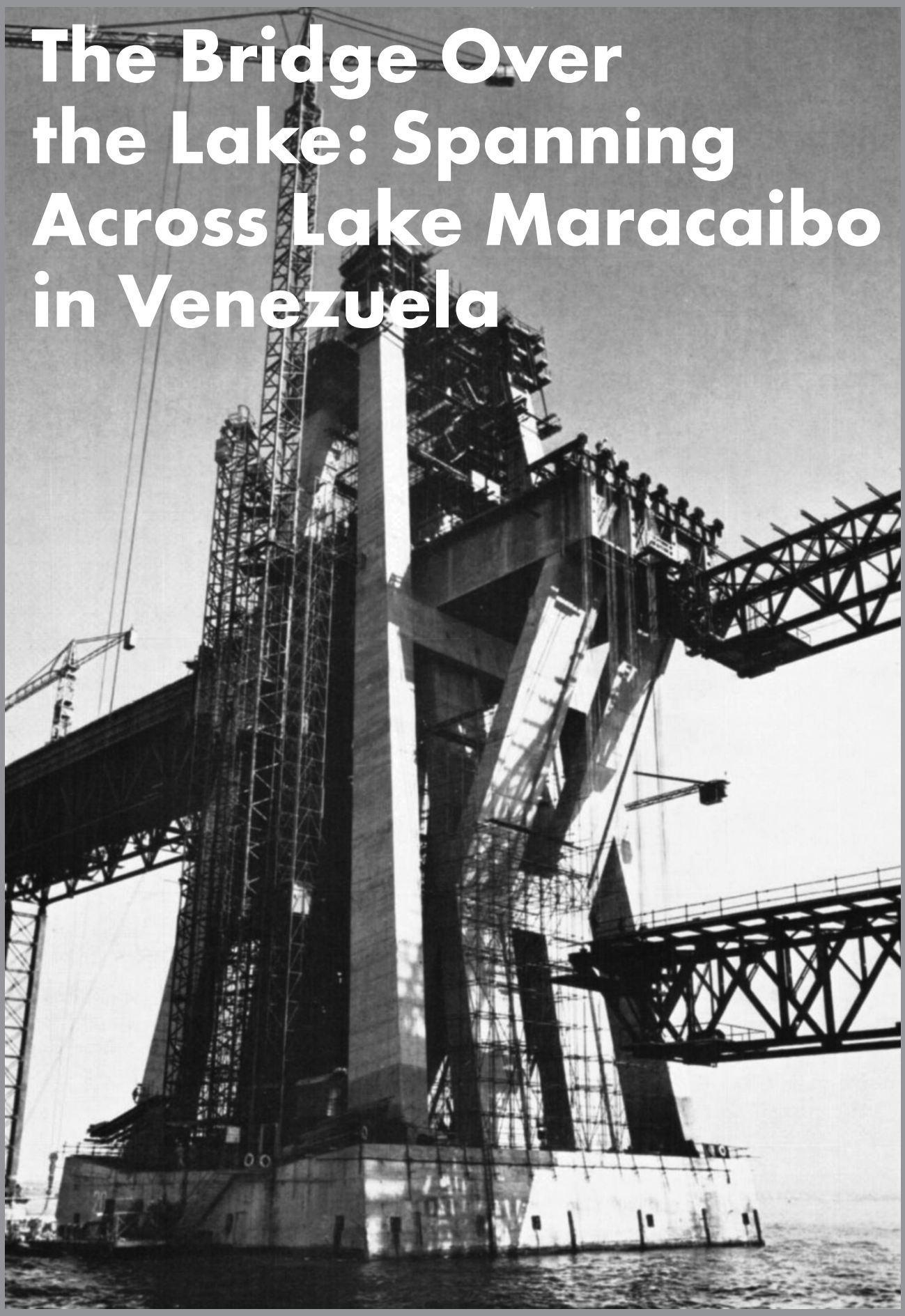
The Bridge Over the Lake: Spanning Across Lake Maracaibo in Venezuela



THE General Rafael Urdaneta Bridge spanning over Lake Maracaibo in Venezuela (1958–1962), designed by Ing. Professor Riccardo Morandi, a masterpiece of Modern engineering, is now a Modern Landmark at Risk. The remarkable and little known story of the construction of this structure "could not be accomplished by a handful of men. From planning to financing, from design to construction, a great number of Venezuelan and European engineers worked jointly in Wiesbaden, Caracas, Rome, Maracaibo, Zürich, Paris, and Lisbon. In this way, one of the most outstanding structures of our time was erected within the stipulated—and brief—construction time."[1]

By Hannia Gómez and Rino Montiel

"When I am going to Maracaibo and begin the bridge to cross, I feel such a strong emotion that my mind begins to and begin the bridge blur strong emotion."[6]

Maracaibo 15

A Lake Façade

THE city of Maracaibo has in the Bridge across Lake Maracaibo, Venezuela, (or "Bridge Over the Lake," as it is commonly known), a monumental Modern city gate of territorial importance like no other city in Venezuela, and maybe in the world.

The bridge can always be seen from the city of Maracaibo. Its unforgettable architecture draws a modern skyline on the lake surface, completing the horizontal and extended skyline of the city itself. The bridge is the main sign of the Modernity of Maracaibo: it is its façade on the lake, and its upmost Modern landmark.

This masterpiece, built in the period 1958–1962, "was recognized at its time as one of the greatest works of modern engineering, enhancing its majesty the fact that it crosses the lake of Maracaibo, the largest in South America and a large reservoir of oil fields."[3] It is the subject of enduring national pride, having been designated on July 16, 2001, as a Good of Cultural Interest of Zulia State, and listed as a National Landmark on August 21, 2002.

Almost a decade after these landmark designations, the dramatic decay of its overall structure and the increasing difficulties to preserve its original qualities situates it as a Modern Monument at Risk, in heavy need of attracting the international attention of the scientific community.

Building a Bridge Across Time

The most important record and unique compilation of the history of Bridge General Rafael Urdaneta was published in a non-commercial book in 1963 in Germany by Dr. Ing. Hanns Simons, Heinz Wind, and W. Hans Moser. It is called *The Bridge Spanning Lake Maracaibo in Venezuela: The General Rafael Urdaneta Bridge*.[4] Most of the information and illustrations that we include here come from that book which is a landmark in itself.

Every single step of the construction process is there described thoroughly with wonderful drawing schemes and photographs. Running through the pages is like jumping back to an era of excellence, courage and building genius.

Bridge Will Assist Communications and Economic Development

By 1961, Venezuela "had an annual petroleum production of 150 million tons, and in the Western World it was second only to the United States as a producer, ranking first as a petroleum exporter. 70% of the oil produced came from the Maracaibo area." The reserves at that time were "among the richest in the world."[5]

Until 1956, "Maracaibo, remained physically distanced from Venezuela. Zulia State's economy was fundamentally based on port activity, and it was easier to travel to the islands of Aruba and Curaçao than to Caracas, the capital city."[6] In the rest of the country "the development of industry and agriculture, and the exploitation of mineral resources were hampered by the long distances to be travelled in difficult terrain. Consequently, economic development essentially called for the construction of new, and the improvement of existing communications." In addition, "new and improved communications with neighboring countries were required to provide transportation facilities. Improvement of the Pan-American Highway, comprising the Lake Maracaibo Bridge, ranked high among the tasks to be handled."[7] The bridge was an important solution to link to the international road network.

What was called at the time "The Oil Country" on the east shore would be "finally connected with Maracaibo. Venezuela's major oil-fields are located in the eastern part of Zulia. There—between Cabimas and Mene Grande—petroleum from the inland and offshore wells is collected and piped, field-processed and transferred to oil tankers. The oil companies have their head offices,

< General Rafael Urdaneta Bridge.
A service girder is being raised into position.

wharves, repair shops and utilities at Maracaibo, where, on the western shore of the lake, are also situated the harbor facilities and the international airport".[8]

From Planning to Contact Award

Never before a bridge of such proportions had been built as a reinforced and prestressed concrete structure. Its total length of 8,678 m, five 235 m main spans and 45 m headroom launched this bridge in the late 1950s as the longest bridge of this kind in the world.

In the initial stage, the Venezuelan Government "carried out extensive investigations to determine the most favorable point for crossing the lake, be it by bridge or tunnel." Five routes were tested. "Routes A to E were tested with regards to topography of the lake bottom, type of subsoil, navigation requirements and, in particular, in respect of connection with Maracaibo's traffic system. From all these, Route D provided the best solution in that it gave a direct connection between the new international airport and the oil–fields on the east shore of Lake Maracaibo. A further advantage of this route is that it runs at right angles to the shipway direction of current, which makes navigation under the bridge much simpler."

Having thus established the most suitable location, "the Government of Venezuela in 1956 called for bids for a 9,000–metre–long structure along Route D. Bidders were invited to offer a bridge or a tunnel, or a combination thereof. The structure has to have four highway lanes, a single–track railroad and openings."[9]

It was in this way that "from different parts of the world proposal began to arrive: tunnel and bridge projects or their varied combinations."[10]

First international Tender Action (1956)

Ten firms were invited to tender. They submitted eighteen varied designs. Four of these designs "would permit a continuous flow of road and rail traffic, regardless of shipping."[11] The other designs "provided level railway

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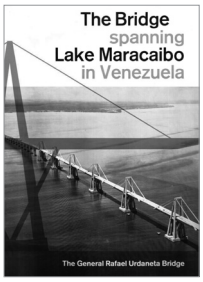
Figure 1. The bridge across the lake can be always seen from the city of Maracaibo, Venezuela.

Figure 2. Satellite view of Maracaibo with the General Rafael Urdaneta Bridge, Venezuela, http://www.skyscrapercity.com/

Figure 3. Cover of the book compiled by Dr. Ing. Hanns Simons, Heinz Wind, and W. Hans Moser, *The Bridge Spanning Lake Maracaibo in Venezuela: The General Rafael Urdaneta Bridge*, Wiesbaden-Berlin, The Bauverlag GmbH, 1963.

Figure 4. The bridge is an important link to the international road network.



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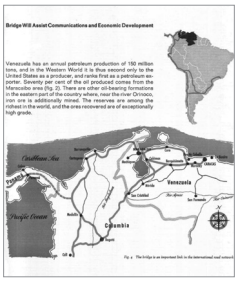

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and road approach sections as far as the central spans. For rail traffic there was then a vertical lift bridge, and for road traffic a tunnel or a separate bridge to link the approach sections."[12]

The story of this incredible competition of designs is in itself an issue for further analysis, waiting still to be told.

Second International Tender Action (1957)

The tenders submitted during the first action had to be abandoned, "because of fresh stipulations about the shipping and highway authorities. Accordingly, in 1957 the Venezuelan Government invited the same selected firms to submit new bids in order to take account of the changed conditions.

It was specified that the free central span of the bridge should have a 400 m waterway, and that on either side of this there should be five openings each giving a waterway of 150 m. It was also specified that these eleven openings should have a 45 m vertical clearance and be located above the natural shipping channel.

Twelve bids were submitted; they ranged from 284 million to 760 million Bolivars (at that time the exchange rate was 3.35 Bolivars to the American dollar). With one exception, all the designs provided for a steelwork superstructure. Only one tender submission was based on an all–reinforced and prestressed concrete structure."[13]

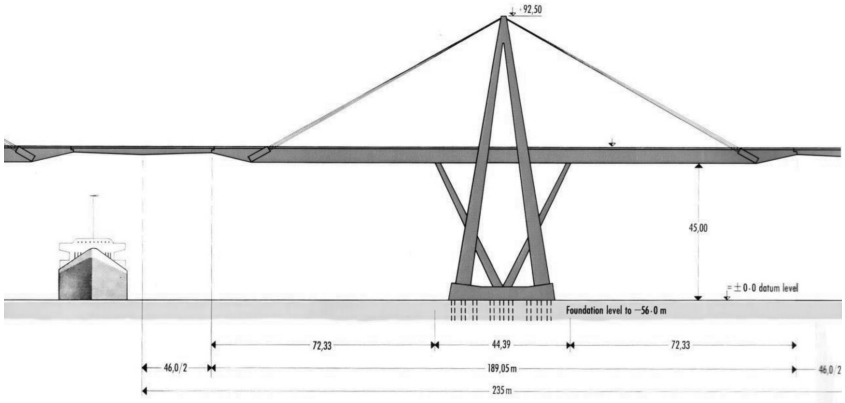
The government commission recommended the acceptance of this bid because:

1. Greatly reduced maintenance costs. Because of the climatic conditions in the Maracaibo area, the annual upkeep of a steel structure was estimated at two million Bolivars.
2. The visual appeal of the design.
3. Less foreign exchange would have to be spent on imported materials.
4. A large number of Venezuelan engineers and skilled labor would be given the opportunity of acquiring experience in prestressed concrete fabric.

Thus, on May 25, 1957, the Venezuelan Government approved the design and accepted the bid of 329,580,136 Bolivars. The finalized contract was signed in Caracas, on August 15, 1957."[14]

The Men Behind The Design

But, who were the bid winners? The Venezuelan Ministry of Public Works awarded the contract for the design



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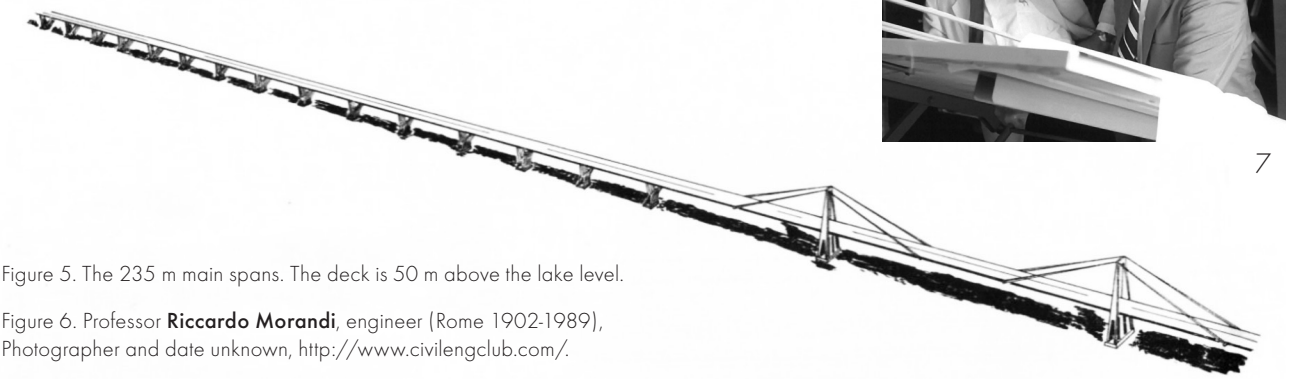

Figure 5. The 235 m main spans. The deck is 50 m above the lake level.

Figure 6. Professor **Riccardo Morandi**, engineer (Rome 1902-1989), Photographer and date unknown, http://www.civilengclub.com/.

Figure 7. **Precomprimido C.A.** founders, engineers **Oscar Benedetti** and **Juan Otaola Paván**, circa 1950. *Universidad Católica Andrés Bello*, Caracas.

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Figure 8. Professor Ing. **Morandi**'s design for the second tender.

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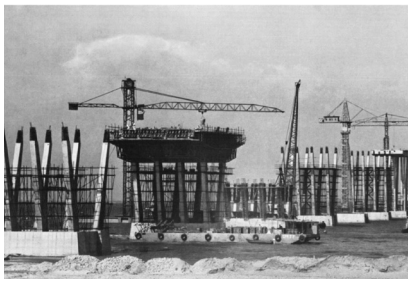

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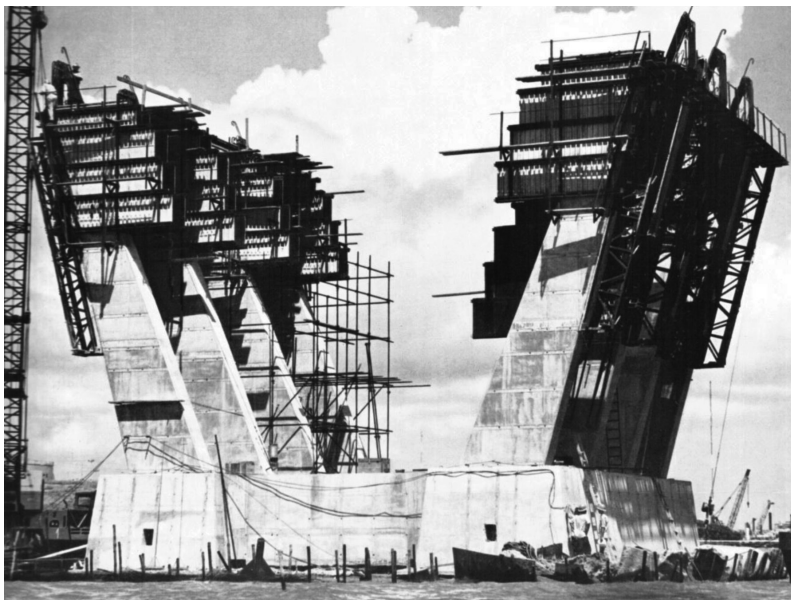
and construction of the new bridge "to the Consortium *Puente Maracaibo*. The Consortium comprised Precomprimido C.A., from Caracas, Venezuela, and Julius Berger A.G., from Wiesbaden, Germany. Firms associated with included Grün & Bilfinger A.G., Mannheim, Philipp Holzmann A.G., Frankfurt a. M., and Wayss & Freytag K.G., Frankfurt a.M., all of Germany. Most importantly, a design by Professor Ing. Riccardo Morandi, Rome, "served as the basis for the structural analysis and detail plans."[15]

World-known Professor Morandi was born in Rome in 1902 and graduated in Engineering also in Rome in 1927. He was an internationally acclaimed engineer, "who practiced as an international counselor in Building Construction Techniques and as a Professor in charge of Bridge Form and Structure courses at the *Facoltà di Architettura dell'Università di Firenze*. Before winning the international competition for the bridge over lake Maracaibo, he had won in Venezuela in 1951 an international competition to build a bridge in the zone of Pagüita in Caracas and had built a bridge over the Tuy River, close to the capital."[16]

Precomprimido C.A. is since 1951 "Venezuela's most important engineering and construction company. Its founders, engineers Juan Otaola Paván and Oscar Benedetti, were pioneers in Venezuela in the construction of highly engineered works. Theirs was the first company to use prestressed concrete in the country. Among their other Caracas important engineering works are the New Republic Viaduct (also with Riccardo Morandi, 1954) and the famous La Gaviota Bridge (1955)."[17]

The Consortium was also conformed by the renowned German enterprise founded in 1890, Julius Berger A.G., and engaged Professor J. Kérisel, Paris, "to handle the particularly complex aspects of soil mechanics. The National Laboratory of Portugal, Lisbon, was commissioned by the Venezuelan Government to carry out model tests to prove the fundamental principles and structural analysis results. The examination of the structural analysis and working drawings prepared by the Consortium and the control of design were entrusted to the late Professor P. Lardy, G. Schnitter, and Dr. F. Stüssi, of the Swiss Federal Polytechnic Zürich. The excellent co-operation of all concerned made it possible to complete the prodigious construction, including all design work, within the contract time of forty months."[18]

An immediate start was made on equipping the site.



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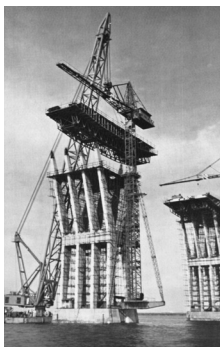

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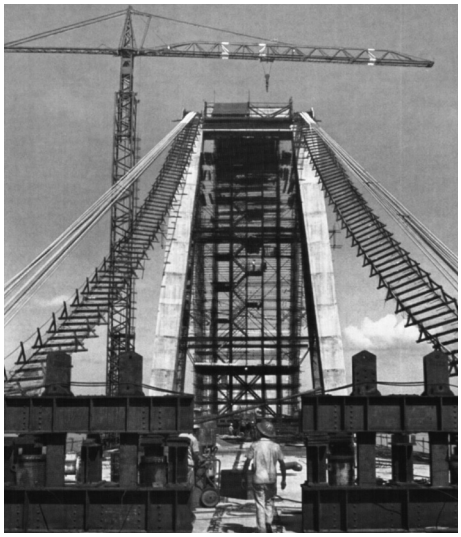

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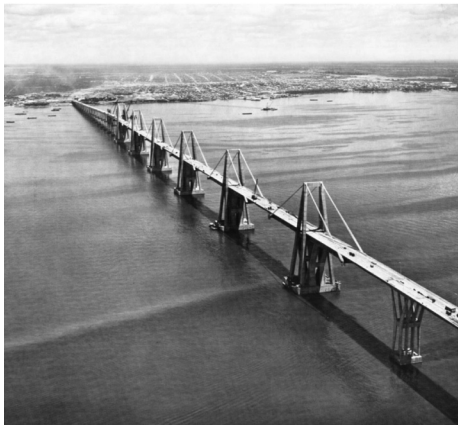

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Figure 9. Site seen from the air.

Figure 10. Concreting pier cap.

Figure 11. Structures 22, 23, 24 and 25 under construction.

Figure 12. Handling a 6-metre-long pile.

Figure 13. The Ajax 250 T floating crane handles 46.60 m precast girders.

Figure 14. Climbing shuttering for V-shaped piers in place.

Figure 15. The Giraffe 125 T floating crane places a service girder on one of the two highest piers of the 85 m spans.

Figure 16. Trestle pier towers 49.50 m into the sky.

Figure 17. Bridge ropes were pulled on the catwalks up to the roller saddle and down the other side.

Figure 18. View of center spans.

Nevertheless, in January 1958, operations had to be suspended because a new government came in to power. The dictatorship of General Marcos Pérez Jiménez had come to an end after a major popular rebellion. On February 13, 1959 Rómulo Betancourt takes office to rule the country for the second time, in a term that "was marked by the development of the oil industry in Venezuela with its adherence to OPEC", and the building great civil works.[19] It was his duty "to inaugurate the work on August 14, 1962."[20]

Fortunately in the meanwhile, the Ministry of Public Works managed "to discuss with the contractors ways of reducing the construction costs. As there would have been no immediate need for a railroad track across Lake Maracaibo, it was decided that this part of the project should be dropped. Also, at the request of shipping interests, the proportions of the main spans were amended. The design was revised to give five openings, each having a 200 m width of waterway, and the original 400–metre–wide central opening was deleted; the vertical clearance was to be 45 m.

In April 1959 work was started."[21]

Principles of Winning Design

Maracaibo is not situated in a seismic area, but it is not immune to shock waves from earthquakes in adjacent regions. As is written in the book, "the employer required

that, should one span of the bridge be affected by an earthquake disturbance, the adjoining spans would not also suffer damage. Therefore, the design provided for all members to be of the statically determinate type.

In order to complete the 8, 678–metre–long bridge in the short contract time, it was essential that, wherever possible, uniform members should be used. This enabled numerous units to be prefabricated at a plant on shore, specially equipped for the purpose.

Starting from the low eastern shore, the structure features a 406–metre–long embankment, after which come twenty 36.60 m spans. This effective span was decided upon for the railway and road bridge, and had to be adhered to because the foundations had been completed when it was decided that the bridge should be for road traffic only. Then follows a section having seventy–seven 46.60–metre–spans, initially, this is 5.5 m above water level and then rises at a gradient of 0.45% and ultimately at a gradient of 2.47% to reach a height of 24 m. Up to this point the 46.60–metre–spans provide openings of balanced proportions. But if this span had been retained for the next section of the bridge, extending to a height of 50 m, the design would have been monotonous and the piers disproportionately high.

Therefore, the span was increased to 85 m, and instead of plain piers, V and H trestle piers were employed; on top of them were mounted 39–metre–long caps, thereby permitting the continued use of the 46.60–metre–girders as suspended spans. As the height of the bridge increases, the V shape of the trestle piers is gradually transformed to an H by lengthening the pier legs in their lower parts. The size of the caps, V–sections of the piers and cross beams remains constant. Consequently, only minor changes were required in the centering, shuttering and reinforcement, from one pier to another. This facilitated and accelerated the construction operations.

Two special trussed steel centering were fabricated for the caps. They had high–quality plywood shuttering. The shuttering and practically all the reinforcement were assembled on these centering on land, and a complete service girder was placed in position with the aid of large floating cranes. It was extremely difficult to bridge the navigation openings of 200–metre–waterway and 45–metre–headroom by a reinforced concrete structure.

To this end, for the first time in the world, five large tied cantilever bridges of concrete, having 235 m spans, were designed and constructed. The inclined ropes for the cantilevered girders pass over 92.5–metre–high reinforced concrete towers. Extensive investigations and calculations were necessary to determine the complex system of forces in the ropes, cantilevered portions and reinforced concrete towers."[22]

Bridge Administration (1962–1990)

Forty months after the works had begun, the bridge was ready to start operating.[23]

From 1962 until 1990, "the management of the bridge was done by the National Government through the Ministry of Finance, who performed the activities of collection and administration of funds, and by the Ministry of Public Works, responsible for maintaining the structure.

In December 1989, the Congress of Venezuela transferred directly to the states the conservation and use of all the roads, bridges and highways in their territories. On July 26, 1991, the Zulia State Legislative Assembly enacted the "Law according to which the Zulia State assumes the Conservation, Management and Use of the bridge General Rafael Urdaneta over Lake Maracaibo."[24]

Preservation Policies (1990–2009)

According to a concern for keeping in optimum condition the bridge structure, the Zulia State Government assumed as a priority the allocation of investments for the rehabilitation and continuous improvement of the bridge's conditions.

The main objective was to restore the structure to its "brand new" condition, taking into account the bridge's original load capacity and levels of service."[25]

Maracaibo Bridge is Falling Down

In May 2009, the Venezuelan Government decided to re–centralize again the management of the bridge. Since then, an increasing deterioration began. This decay lasts until today. Minor and major maintenance "is only performed to correct problems and as a reaction to crisis."[26]

In 2010, the *Colegio de Ingenieros de Venezuela* publicly expressed its alarm. It said that the bridge is in an emergency, "due to a crack in its structure which has yielded several centimeters." In this regard, they asked for its immediate closing: "a comprehensive review of the entire structure is required, and can no longer be postponed." And they warned that "a partial collapse might occur." The main problem is "the degradation of concrete in several of the bridge parts" and the decay of the ropes. Also, "the falling parts of concrete pieces, leaving the steel uncovered."[27] Corrosion damage is practically everywhere.

Traffic in the bridge over the lake has increased enormously, but as the control scales are damaged, no one surveys the number of vehicles going upon it today. A very dramatic situation for a structure designed for a maximum of 20,000 vehicles per day, which now is said to be having 40,000 per day.

Local fishermen and marines from the Lake Maracaibo also do their own alarm call to the national and inter-

national community: "If you see the bridge from below, you would not want to pass over it."

Notes

1. Dr. Ing. Simons, Hanns; Wind, Heinz and Moser, W. Hans, compilators, *The Bridge Spanning Lake Maracaibo in Venezuela: The General Rafael Urdaneta Bridge*, Wiesbaden-Berlin, The Bauverlag GmbH, 1963.
2. *"Cuando voy a Maracaibo/y empiezo a pasar el puente/siento una emoción tan grande/que se me nubla la mente"* Maracaibo 15, from the Zulian gaita *Cuando voy a Maracaibo*, 1960s.
3. Remark from engineer Rino Montiel, ex-Director of the General Rafael Urdaneta Bridge.
4. Simons, Wind and Moser, *Op.Cit.*, 1963, 19.
5. Simons, Wind and Moser, *Ibid*, 1963, 5.
6. Rino Montiel.
7. *Idem*, 1963, 5.
8. *Idem*, 1963, 6.
9. *Idem*, 1963, 7.
10. Rino Montiel.
11. Simons, Wind and Moser, *Op.Cit.* ,1963, 8.
12. Simons, Wind and Moser, *Ibid.*,1963, 9.
13. *Idem*, 1963, 9.
14. *Idem*, 1963, 10.
15. *Idem*, 1963, 1.
16. Santini, Pier Carlo and Marini, Giusseppe Luigi, "Riccardo Morandi", *Catalogo Bolaffi della Architettura Italiana*, Torino, Giulio Bolaffi Editore, 1966, 380-383.
17. Precomprimido C.A., http://www.precomprimido.com/
18. Simons, Wind and Moser, Op.Cit., 1963, 1.
19. Rómulo Betancourt, http://es.wikipedia.org/wiki/R%C3%B3mulo_Betancourt
20. Rino Montiel.
21. Simons, Wind and Moser, Op.Cit., 1963, 10.
22. Simons, Wind and Moser, Ibid., 1963, 12-14.
23. *Idem*, 1963, 120-121
24. Rino Montiel.
25. Rino Montiel.
26. Rino Montiel.
27. "*Expertos piden declarar en emergencia al Puente sobre el Lago de Maracaibo*" http://ovario.wordpress.com/2010/02/19/expertos-piden-declarar-en-emergencia-al-puente-sobre-el-lago-de-maracaibo/

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President/founder of the Caracas-based foundations *Centro de la Ciudad* and *Fundación de la Memoria Urbana*. She studied Architecture at the FAU *Universidad Central de Venezuela* in Caracas and Urban Design at the GSAPP Columbia University in New York City. She is author of the books *El Cerrito: Gio Ponti's masterpiece in Caracas* (2009) and *Gego, Architect* (2007), and of numerous texts dealing with architectural and urban culture. A writer, architecture critic and curator, she is also founder and Vice president of the Venezuelan Chapter of **docomomo**.

Rino Montiel

Civil Engineer and a MS in Business Administration and Project Management from the *Universidad del Zulia* and the *Universidad Rafael Urdaneta*, Maracaibo. He worked for twenty-one years at PDVSA (Petróleos de Venezuela S.A). For a four-year period he was Director of the Bridge over Lake Maracaibo. He currently works with the Government of Zulia State.

The authors want to give special thanks to architects Jasmine Lizcano, Director of the *Centro Rafael Urdaneta* in Maracaibo, Zulia State, and Frank Alcock, grandson of engineer Gustavo San Román, who participated with his firm VICA in the tender actions for this bridge, both **docomomo** Venezuela members.

All figures except 2 and 5 are from the book *The Bridge Spanning Lake Maracaibo in Venezuela: The General Rafael Urdaneta Bridge*, Wiesbaden-Berlin, The Bauverlag GmbH, 1963.