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Bridge Engineering in Argentina

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Bridge Engineering in Argentina

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3.1 Introduction

Argentina is a large country, with a continental area of approximately 2.8 million km$^2$ and has a population of about 40 million people. It is located at the extreme south of the American continent, between Chile on the west and the Atlantic Ocean on the east. It is about 3900 km long from north to south and 1400 km wide from east to west (Figure 3.1).

3.1.1 Geographic Characteristics

Argentina’s terrain includes the Andes Mountain chain all along the west border with Chile, a large plain in the center of the country interrupted by only a few hills, and a large fertile extension of land known as the Pampas region to the east. There are only two rivers in the country that are navigable by freights: the Uruguay River and the Paraná River. The enclosed area between these two rivers is known as the Mesopotamian region. There are several other important rivers that cross the country from west to east, flowing into the Atlantic Ocean. Said rivers are the result of the confluence of many small tributaries that descend from the mountains, forming low-speed plain rivers.

FIGURE 3.1 Physical map of Argentina, Buenos Aires City, and their main rivers.
3.1.2 Historical Development

The transportation infrastructure of the country is derived of its history and geography. During the Spanish colonization (sixteenth and seventeenth centuries), Argentina was part of the Viceroyalty of Peru, and the road transportation of goods came from all over to the capital Lima, across the high plateau of the northern Andes, and from there to Spain via Panamá. Only small bridges were required by these very scarce transportation demands. In 1776 the viceroyalty of Rio de la Plata was created by Spain in order to simplify the trade that was redirected to its capital, Buenos Aires, which grew as unique port of the southern colonies.

Around 1810, Spain began to lose its power and all the South American colonies became independent countries. Trade had to go through the port of Buenos Aires, which became large and rich thanks to taxes imposed on trade. The road network also was improved and changed accompanying these transformations, becoming a radial system in which all the roads went towards the port of Buenos Aires. Trade was essentially composed of products of the land, agricultural products, and meat. The country soon became one of the most important food and leather suppliers in the world.

Although there was a lot of immigration in the nineteenth century, the population was still very small. At present, two-thirds of the 40 million people that form the total population of the country live and work near Buenos Aires and its surroundings, in the principal cities that grew in the littoral of the country as main ports. The average density for the total area is only 14.3 people per square kilometer, leaving the country ranked 200th among the nations in the world. Also, due to the independence war, the Paraná River and all of Mesopotamia were isolated, leaving them disconnected from the whole area of the country, as a natural barrier against eventual attacks from the neighbors. There was no interest in building bridges over the main rivers (Paraná and Uruguay) until well into the twentieth century.

Many civil wars took place in the first half of the nineteenth century, preventing the economic and technical development of the country. The first engineering school was founded in 1877, more than 60 years after independence. Between 1870 and 1914, nearly all of the country’s railway network was built by British and French companies. Local engineers did not play any role in designing and building the most important bridges of the network. To allow goods to be exported through the port of Buenos Aires, the network was developed, according the interests of the foreign companies, as a radial one. The main river (Paraná) was crossed by ferry. The first railway crossing over the Paraná River was not built until the 1970s (see Section 3.7.2).

In 1932 the Dirección Nacional de Vialidad (DNV; National Highway Administration) was created and the construction of roads and bridges received a major boost. Previous bridges were built by local communities or by railway companies to allow the freight to reach the port. Until late 1930s the industrial development of the country was almost nonexistent and local construction companies were not able to build large bridges. Most of the important bridges were designed and built by foreign engineers and contractors. They usually came from Europe, mainly from Germany. Germany had a strong influence on Argentine engineering and, as a matter of fact, the Argentine standards for concrete, steel, and bridge structural design are influenced or even translated directly from the DIN code (Deutsches Institut für Normung e. V.). Since almost the year 2000, there has been a strong tendency in the engineering organizations to switch towards the American Standards (ACI, AISC, and AASHTO) but, due to the great inertia of Argentina’s institutions, this change might take too long.

3.1.3 Historical Bridges

3.1.3.1 Old Bridge of Areco

One of the very few bridges that survived from the days of the independence wars is the “Puente Viejo de Areco” (Areco Old Bridge), shown in Figure 3.2, built in San Antonio de Areco between 1854 and 1856 and designed by a French engineer whose last name was Mollard. It was the first toll bridge in the country.
The arch bridge is 18 m long. It is composed by two parallel masonry walls that are filled with soil. Two additional circular holes at both sides of the arch increase its hydraulic capacity. Its rise-to-span ratio is 1:5. The arch is 60 cm deep at the center. It rests on spread foundations. The bridge was restored in 2002.

3.1.3.2 La Boca Aerial Transporter Bridge

This old bridge spans the Riachuelo River connecting Buenos Aires City Federal District to Maciel Island (Buenos Aires Province), and is an important tourist attraction of the La Boca neighborhood at present. The British South Railway Company was authorized to build the bridge in 1908 and donated it in return for various tax exemptions granted by the national government. When completed in 1914, it was named Nicolás Avellaneda, after the Argentine president who played an important role in the federalization of Buenos Aires in 1880. The original purpose was to serve pedestrians, automobiles, street cars, wagons, and trams on its 8 m × 12 m platform, across a length of 65 m (Figure 3.3).

The structure leaves a 50 m × 40 m navigational clearance. The iron parts of the bridge were built in England and then assembled in Buenos Aires and rest on the foundations built by National Port Authority, eight 4 m diameter 24 m high concrete piles. The bridge was opened to traffic on May 30, 1914. It has been in disuse since 1939 and was closed in 1960. It was declared a Cultural and Historical National Monument in 1993 to prevent it from being dismantled. These types of bridges are of a valuable typology of engineering, developed during the industrial revolution. Little by little, technological advances in construction made them disappear, leaving, at present, only eight of this kind worldwide.

3.1.4 Bridge Infrastructure

3.1.4.1 Roadway Bridges

The Argentine Republic has approximately 500,000 km (310,000 mi) of roads of different types or categories. Around 40,000 km (25,000) of them constitute the primary or national network and 180,000 km are the secondary or provincial network. The remaining 280,000 km (175,000 mi) forms the tertiary network, dependent on the municipalities. Only 61,000 km (38,000 mi) from the 220,000 (138,000 mi) that form the primary and secondary networks are paved, whereas 37,000 km (23,000 mi) have had some type of improvement (with gravel or some type of stabilization). The remaining 120,000 km (75,000 mi) are rural roads, without any stabilization.
Recalling that Argentina possesses a continental surface of 2.8 million km² (1.1 million mi²), it is seen that the country has an underdeveloped road structure, which owes itself partly to its scanty population, a problem that is aggravated by the high demographic concentration in certain zones. The primary network of the country, which includes 3100 bridges, is under the administration of the Dirección Nacional de Vialidad (DNV), an entity of the National Secretary of Public Works, whereas the secondary network depends on the DNV of each province, under the domain of each one of the provincial governments. There are around 5000 bridges in the secondary network.

The primary and secondary networks were formed in the 1940s, and, under internal financing, underwent an epoch of relative improvement in the 1960s until the middle of the 1970s. As the financial situation of the State was deteriorating throughout the years, the successive governments were turning the funds from the DNV towards other destinations, diminishing the road construction and maintenance. In the 1990s, near 10,000 km (6200 mi) of routes were granted in concession by toll to private companies. There are around 1800 km (1100 mi) of expressways, all of them granted in concession by toll. The concession system shares 75% of the whole traffic of the country.

3.1.4.2 Railway Bridges

The construction of the railway network in Argentina began in the second half of the nineteenth century. Most of the railway system was constructed between 1870 and 1914 by the English and French, leading to the country to occupy the tenth place in the world, with approximately 47,000 km (29,000 mi) of railroad. Rail transport was an engine of the development of the country. After the first world war, there were no increases in the railway network and in 1946, the extensive network went to the hands of the State, suffering a yearly deterioration because of the erroneous political decisions of the authorities. At present, the railway Argentine network has an extension of 31,000 km (19,000 mi), with three track gauges, which is an inconvenient situation for its operation.

In 1930, Argentina’s railway network of 40,000 km (25,000 mi) represented 45% of the total of South America and it was the third overall, after the United States (400,000 km) and Canada (65,000 km). At this time, trains were carrying more than 50 million tons/year, whereas now, only the 36% of that value is moved by railways. The decline also reached to the inter-city traffic of passengers, which nowadays is 2.5 millions of persons per year, a tenth of those who were mobilizing by train 25 years ago.
The development of railway bridges has been according to the development of the rail network. Almost no railway bridges have been constructed in the last 70 years, with the exception of the cable-stayed Zárate–Brazo Largo mixed bridges (see Section 3.7.2). On the contrary, there are many cases of railway bridges that have been modified to adapt them for road traffic (see Section 3.6.1). There is no inventory of the railway bridges in the country but an estimation of around 2500 bridges serves as a good figure.

### 3.2 Design Practice

The evolution of bridge design practices in Argentina has followed a path directly related to the evolution of the country. During colonial times, the few bridges we know about were built in wood and haven’t survived the test of time. However, since the eighteenth century, some documents and design plans about the construction of important bridges have survived. Until 1810, bridge construction was executed in the state-of-the-art knowledge of the colonial government, the Kingdom of Spain.

After independence, the country intensified commerce with other nations of Europe, mainly with England, France, and Germany, which strongly invested in the country. Said investments were accompanied by new technological advances in design and construction that were absorbed by the locals. These countries also had great academic influence on the universities of Argentina and particularly on the training of engineers. After the creation of the DNV in 1932 and with the schools of engineering well consolidated, many excellent bridge designers had the opportunity to apply their knowledge and creativity in building bridges all around the country.

#### 3.2.1 Design Specifications for Highway Bridges

In 1952, the DNV published and put into effect the “Basis for Calculation of Reinforced Concrete Bridges,” which contains specifications for loads and their combinations and specifications for the design of reinforced concrete sections based on the allowable stresses design method. This regulation was an almost literal translation of the German Standards (DIN) of the 1930s.

In reference to the design of reinforced concrete sections, this regulation became rapidly obsolete and the design of reinforced concrete for bridges was carried out following the requirements of the standards for the design of building concrete structures, also an adaptation of German DIN standards. By contrast, specifications of loads are now still used with minimal change to the distributed load, decreasing as a function of the length of the influence line-loaded length to get maximum stresses.

The inconsistency involved in using loads from one standard and dimensioning according to another standard has not been an obstacle to the design of bridges of moderate span so far, and these have produced a great degree of safety. However, for large projects, DNV has accepted the use of foreign standards, mainly those of AASHTO and Eurocodes, in its different editions at the time of design. At present, the government administration office CIRSOC (Research Center for Safety Regulations of Civil Works) has created a commission to update the regulations for bridge design based on an adaptation of AASHTO standards.

#### 3.2.2 Design Specifications for Railway Bridges

Since the beginning of railway construction in the country, British companies built and operated them, as well as designed and manufactured in England a large number of bridges that were then assembled in Argentina, according to their own specifications. In 1909, a National Administration of Railways was created to manage the rail network. In 1949, the property of the railways was transferred to the government. The new Administration of Railways (Ferrocarriles Argentinos) issued standards for the structural design of steel and concrete bridges that are still in use.
Because the railways haven’t had further development in Argentina and have been losing share in the transport of cargo and passengers, there are virtually no modern railroad bridges. Only a few structures for passage of streets or roads under railway lines in operation are now constructed, but these small structures don’t require special technologies or designs.

### 3.3 Concrete Girder Bridge

#### 3.3.1 Agustín P. Justo–Getulio Vargas Bridge

This bridge, shown in Figure 3.4, was built over the Uruguay River, a natural boundary between the east of Argentina and southwest of Brazil, linking Paso de los Libres city (Argentina) with Uruguayana city (Brazil). It is a parallel and separate roadway–railroad dual-purpose bridge.

When completed in 1945, it became the first physical and a very important connection between the two largest countries in South America and the first long bridge over the Uruguay River. Its importance meant both countries made huge efforts to build it during World War II.

The bridge was designed by a joint committee that consisted of three members of each country. Among them was the famous Argentinean military engineer Manuel N. Savio. Each country worked independently on its construction and met halfway. On the Argentinean side, the contractors were Administración de Vialidad and Ferrocarriles del Estado. The work began in December 1942 and ended in February 1945. It was opened to traffic in December 1945.

The bridge’s total length is 1419 m (35 m + 40 × 38 m + 35 m + 40 × 38 m + 35 m), symmetrically composed by a simply supported 35 m side span, 10 continuous four-span frames of 38 m and a simply supported center span of 35 m. The superstructure comprises two independent decks with an overall width of 12.9 m. The roadway deck carries two 3.15 m wide lanes and 1.2 m sidewalks on each side. The remaining 3.85 m are occupied by the railway track. Both decks are supported by two haunched box beams 2.5 m deep at midspan and 4 m at the abutments. The whole structure is cast-in-place reinforced concrete. The piers are wall type and integrated to the superstructure. They are founded on spread foundations on a sound rock stratum. Due to the fact that this section of the river is not navigable, the vertical clearance over water level is only 3.7 m.

![Figure 3.4](image-url) The Agustín P. Justo–Getulio Vargas Bridge in a stamp from 1947, as a testimony of its importance for the country.
### 3.3.2 Manuel Elordi Bridge

Built on National Route 34 to span the Bermejo River in Salta Province, the Manuel Elordi Bridge was the country’s first prestressed concrete bridge. Designed by engineer Helmuth Cabjolsky (a German resident in Argentina), the bridge (Figure 3.5) has a total length of 336 m composed by two continuous beams of three 56 m spans. The cross section is two cast-in-place T-beams. The roadway deck is 7.2 m wide. The piers are concrete rectangular solid walls. The owner is the DNV. The bridge built was an alternative to the original design provided by DNV on reinforced concrete. The contractor was Zarazaga y De Gregorio. It was constructed between the years 1958 and 1961. After this bridge was built, the prestressed concrete technique was expanded all around the country for bridges with spans over 20 m.

### 3.3.3 Colastiné River, Old Bridge

In 1967, the Colastiné River was the only remaining obstacle for the completion of the land transportation between the country’s Mediterranean region and the Mesopotamian region on National Route 168. In December 1967 the completion of the tunnel below the Paraná River was expected to establish an important road connection between the cities, so it was imperative to solve the crossing of the Setubal Lake (see Sections 3.3.4 and 3.3.13) and the Colastiné River.

The bridge (Figure 3.6) is 522 m long. It comprises 10 simply supported equal spans. The superstructure is composed of four 50 m long and 3 m deep precast prestressed T-beams, with an overall weight of 120 tons. The deck slab was cast-in-place. It carries two lanes 4.15 m wide and two sidewalks of 2 m each. The piers are of hollow concrete and supported by spread footings.

There were many technical difficulties with the material of the river bed that affected the construction schedule. The works began in 1957 by the owner DNV, and the bridge was opened to traffic on March 1967. It was designed by contractor Compañía General de Construcciones. At the time of its construction, this bridge established a country record in terms of the length of the precast prestressed beams.

*FIGURE 3.5* The Manuel Elordi Bridge, over Bermejo River in Salta Province, is the country’s first prestressed concrete bridge.
3.3.4 Nicasio Oroño Bridge (New Setubal Lake Bridge)

One transportation obstacle between the Mesopotamian and Mediterranean regions was a transit restriction on National Route N° 168 due to an old suspension bridge over Setubal Lake (see Section 3.9.1), linking the cities of Santa Fe and Paraná. The overall bridge length is 298 m (84 m + 130 m + 84 m) composed of three continuous spans (Figure 3.7). The superstructure was built using the balanced cantilever cast-in-place method and its cross section comprises two 0.32 thick box beams of variable height between 2.2 m and 7 m. The top slab is 10 m wide and the bottom slab is 5.7 m wide. The deck accommodates four lanes 3.75 m wide, two sidewalks of 2.6 m, and a median of 1.5 m which rests on top of a simply supported slab that closes the gap between the two box sections. Two large aqueducts that provide fresh water to Santa Fe are suspended under the deck, between the two box beams.

Both main piers supported on Franki piles are composed of twin thin vertical walls monolithically connected to the superstructure in order to provide the required flexibility for long-term displacements and the necessary stiffness to withstand the high flexural moments transmitted by live load. A curved approach viaduct is on the Santa Fe side. The bridge was designed by Europe Etudes, Societe de Techniques pour l’Utilization du Precontraint (STUP) Argentine branch, and Pilotes Franki.

Construction works began in 1967 by the owner DNV. Contracting was a joint venture between the companies Cristiani Nielsen SA and Pilotes Franki SAIC. The bridge was opened to traffic in March 1970. The large flood of 1983 produced the collapse of the north tower of the old suspended bridge, located only 60 m upstream of the new bridge and an important scouring on the north pier of this bridge. After the preventive closure to traffic, new bored piles were built to retrofit the north pier to a safer situation.

3.3.5 New Puëyrredón Bridge

The New Puëyrredón Bridge (Figure 3.8) was built over the Riachuelo River and links Buenos Aires City Federal District with Avellaneda in Buenos Aires Province, two highly populated metropolitan areas. It constitutes the main southwest access to the city. The overall length of the bridge is around 1300 m. The
main bridge is 187.3 m long (24.5 m + 43.1 m + 46.6 m + 43.1 m + 30.2 m), with five simply supported spans. Approach viaducts are 1026 m long, covering a span range from 8.9 m to 33.4 m. The girders are eight 2.35 m deep, precast prestressed trapezoidal box beams, with weight varying from 100 tons to 200 tons. It was erected using floating cranes. Two independent cast-in-place deck slabs are linked together by a simply supported median 1 m long concrete slab. The deck accommodates four lanes 3.75 m wide and two sidewalks 2.50 m wide, on both sides.

Two bents with two lines of eight circular columns of 1 m diameter are rigidly connected to pile caps. Each pier is supported by 161 m diameter precast prestressed concrete piles composed of 10 segments of 3 m long precast hollow cylinders, brought together by prestressed tendons and reaching a dense sand stratum called Puelchense formation. The northern approach viaduct is composed of simply supported 17.85 m long, 33.40 m wide spans, with 14 precast prestressed concrete T-beams. The southern approach viaduct is a continuous cast-in-place curved trapezoidal box beam, with variable spans ranging between 16.5 m and 37.8 m. Piers are circular columns 1.6 m in diameter and are founded on the Puelchense stratum.

Construction began in 1969 by owner DNV. It was designed by the contractor Empresa Argentina de Cemento Armado (EACA) and was developed by Pretensac. The bridge was opened in 1971 and became a great traffic relief during rush hours. At the time of its construction, this bridge established a country
record due to the fact that precast beams of 200 tons were lifted up into place. The precast segments were erected by a new floating crane that was incorporated to the Port Authority of Buenos Aires fleet, originally conceived for extracting old shipwrecks.

### 3.3.6 Libertador General José Gervasio Artigas Bridge

This bridge (Figure 3.9) was built over the Uruguay River, a natural boundary between the east of Argentina and western Uruguay. The bridge is located near the cities of Paysandú (Uruguay) and Colón (Argentina). The governments appointed a new committee, called COTEPAYCO (Technical Committee for the Paysandú–Colón Bridge), in 1966, which became the owner of this bridge.

The bridge total length reaches 2350.44 m. The main structure is 335 m long (97.5 m + 140 m + 97.5 m), composed by a three-span continuous beam built by the segmental balanced cantilever cast-in-place method. The Uruguayan side approach viaduct is 460 m long with ten simply supported spans of 46 m each. The Argentine approach viaduct is 1555.44 m long, composed by 22 pairs of cast-in-place concrete continuous spans with π sections. The overall deck width is 11.6 m. Roadway lanes are 8 m wide and pedestrian sidewalks are 1.8 m wide per side. Central span piers are composed by two concrete thin-walls. The abutments are open end, spill-through. The vertical clearance for navigation under the center span is 34 m.

The bridge was designed by the engineering firm Cabjolsky–Heckhausen of Argentina. Construction began by a joint venture of EACA, Ing. Odemar H. Soler SA, and Zarazaga y De Gregorio SAIC in September 1970. It was financed by the Ministries of Public Works of both countries. The bridge was inaugurated in December 1975.

### 3.3.7 Guachipas River Bridge

This bridge (Figure 3.10) was built on National Route 22 over the Guachipas River, in Salta Province, and was part of the Cabra Corral Hydroelectric Project. The construction of a dam required that the bridge would have to be built very high, taking into account that an artificial lake would be formed by flooding most of the existing route and the existing bridge over the Guachipas River. The selection of the type of bridge was the result of a combination of economic and safety criteria as well as construction speed.
Safety was extremely important due to the fact that the bridge was to be located in a highly seismic area and any reparation would be impossible after the lake was formed.

The overall length of the bridge is 378.6 m. It comprises eight simply supported spans (46.1 m + 6 × 48.9 m + 39.1 m). The superstructure is constituted by three precast prestressed T-beams 2.5 m deep. The deck has a total width of 10.7 m. It accommodates two lanes 4.15 m wide and two sidewalks of 1.2 m per side. Piers are composed of large hollow cylinders 6 m in diameter, 300 mm thick, and nearly 60 m tall, which rest on a square (6.2 m × 6.2 m) cross-sectional base, 6 m tall. Due to its great height, the piers are among the most outstanding feature of this bridge. The piers are topped with square slabs (7 m × 7 m × 1 m) to support the T-beams. Triangular counterforts assure a very stiff connection in sections of high flexural

**FIGURE 3.10** The Guachipas River Bridge under construction, before (a) and after (b) the filling of the Cabra Corral Dam.
moments. Some piers are supported by a pile cap (15 m × 15 m × 1 m) and 48 Franki piles of 0.53 m diameter and approximately 8 m long. Some of the piers are founded with spread foundations on a highly resisting sandstone stratum.

Construction works began in 1971 by owner Agua y Energía Eléctrica de la Nación, and the bridge was designed by contractors EACA and Panedile Argentina SA. The bridge was opened to traffic in 1974, well before the hydroelectric project schedule. At the time of its construction, this bridge established a country record in terms of the height of the piers. Unfortunately, they can’t be seen after the lake has reached its final water level.

3.3.8 Libertador General San Martín Bridge

This bridge (Figure 3.11) is located over the Uruguay River, a natural boundary between the east of Argentina and the west of Uruguay, linking Fray Bentos (Uruguay) and Puerto Unzué (Argentina). In order to carry the roadway networks of both countries, the governments signed an agreement to build two bridges over the Uruguay River in 1960: the one linking the cities or Fray Bentos (Uruguay) and Puerto Unzué (Argentina) and the other between the cities Paysandú (Uruguay) and Colón (Argentina). On its completion, it became the first physical connection between the two countries and it is still part of the shortest route between the capital cities of Buenos Aires and Montevideo.

Construction began on August 1971 by the owner, COMPAU (Mixed Technical Commission for Bridges between Argentina and Uruguay), with funds submitted by IADB (Inter-American Development Bank). Joint venture COPUI (International Bridge over the Uruguay River Consortium) were the contractors, composed of Entrecanales y Tavora from Spain and Hochthieff from Germany. It was designed by the Uruguayan engineer Alberto Ponce Delgado, owner of the firm INVIAL of Uruguay, and the Italian professor Riccardo Morandi acted as consulting engineer. Technical project management was carried out by a joint venture between designer INVIAL (Uruguay), and SAE (Sociedad Argentina de Estudios). It was opened to traffic in September 1976. Due to its main span of 220 m, it was world’s longest segmental bridge at the time its construction began.

The total bridge length is 3408 m. The main structure is 510 m long (145 m + 220 m + 145 m), with three spans structured as a gerber beam type, with two double cast-in-place arms, built by the segmental

![FIGURE 3.11](See color insert.) Overview of General San Martín Internacional Bridge, between Fray Bentos (Uruguay) and Puerto Unzué (Argentina).
balanced cantilever method, and three 40 m isostatic precast prestressed beams. The two approach viaducts, also gerber-type structures, are composed of 30 m precast prestressed double cantilever arms placed over the piers, which support 40 m isostatic precast prestressed beams spans, thus forming secondary spans of 70 m. Seven secondary spans are placed on the Uruguayan side and the other 17 are on the Argentinean side. A long low-level transition viaduct (1 × 55 m + 27 × 41 m) completes the structure on the Argentinean side. The overall deck is width is 11.3 m, with two lanes of 3.65 m, narrow emergency shoulders of 0.50 m, and pedestrian walkways of 1.5 m width.

The two piers of the main span are composed by two concrete U-shaped walls facing each other. They are 36 m tall, built with vertical sliding forms in order to achieve a navigation clearance of 45 m at the main span. Each of these piers where founded on four, 10 m diameter, cylindrical caissons, driven with the use of compressed air 24 m below water level and reaching a sound sandstone stratum. The abutments are spill-through.

The piers of the main span, over the navigation channel, are protected against vessel collision by an independent protection system. The fences are placed upstream and are designed to absorb the energy of impact by plastic deformation of its reinforced concrete components: piles and plates with heavy reinforcement. There were no approved international standards for the design of that type of protection system during that time. Thus, it was considered an important innovation and it was the first time that a great bridge was protected against vessel collisions of such characteristics in the country.

3.3.9 25 de Mayo Urban Highway Viaduct

This highway viaduct (Figure 3.12) is 10 km long from the junction between Lafuente Ave. and Del Trabajo Ave. to Ing. Huergo Ave. The viaduct, with four 3.5 m wide lanes and shoulders 2.5 m wide in each direction, passes over a highly populated area, and it is the main access to the Buenos Aires international airport. The structure is comprised of two separate viaducts parallel to each other. Each of them consists of continuous beams of six spans of variable lengths from 25 to 30 m depending on the streets and railways to overpass. The cross section is a trapezoidal box lightened by the use of plastic hollow tubes and was cast in place with a sliding formwork adapted to small changes in the length and curvature of the alignment.

FIGURE 3.12  A sector of the 10 km 25 de Mayo Highway (AU-I). (Courtesy of ATEC Ingenieros Consultores.)
The owner is the city of Buenos Aires. Feasibility studies and original design were carried out by ATEC Ingenieros Consultores, who also acted as project managers. The construction and detail design were assigned to Concessionaire AUSA (Autopistas Urbanas SA), with the 20 year usufruct of the tolls. This was the country's first toll-operated urban highway. Construction works began in 1978 and it was opened to traffic in December 1981. The traffic was 70,000 average daily traffic (ADT) at the time it was inaugurated. At present 236,000 vehicles use the highway in peak hours, every day.

### 3.3.10 Presidente Tancredo Neves Bridge

This bridge (Figure 3.13) is placed over the Iguazú River, a natural boundary between northeast Argentina and southwest Brazil, very near Iguazu Falls (see Section 3.10.4), which was declared a World Heritage Site by UNESCO in 1984. Although the agreement to build this bridge was signed by the presidents of both countries in 1972, construction began in January 1983 by COMIX (a mixed committee between countries).

The bridge was built using the segmental, cast-in-place, balanced cantilever method. The superstructure comprises a three-span continuous box beam of 480 m total length (130 m + 220 m + 130 m), and a deck which is 16.5 m wide. The column bents are 48 m tall. The piers are rectangular at their base and then subdivide into two thin-wall columns, monolithically connected to the superstructure on the top to provide the required flexibility to the continuous beam. The piers are founded on 20 1.8 m diameter bored piles, clamped 4 m into bed rock (basalt). The pile caps are prestressed. The abutments are founded on reinforced concrete spread footings.

The bridge was designed by consulting firm Consulbaries (Argentina) and Figueredo Ferraz (Brazil). Construction was carried out by joint venture between contractors Super cemento (Argentina) and Sobrenco (Brazil) and a joint venture between the designers and the firm ETEL (Brazil) was responsible for the technical project management. It was opened to traffic in December 1985, only one month after schedule, which was a real achievement taking into account a huge flood in 1983 that flooded the area for several months.

![Figure 3.13 Overview of Presidente Tancredo Neves Bridge almost completed. (Courtesy of Super cemento SAIC.)](image-url)
3.3.11 9 de Julio Urban Highway

9 de Julio Ave. is an important traffic route of Buenos Aires. It crosses downtown from north to south, with a total length of 18 km. Only two parts of this gigantic project were built, which constitute the present southwest and northern access to downtown. The structures of these two branches are elevated viaducts (Figure 3.14); the south branch is 2.2 km long and links up with the new Pueyrredón Bridge (see Section 3.3.5) and the north branch is 2.7 km long and crosses over the whole railway gridiron while approaching the main station of Retiro and the railway system of the port of Buenos Aires. Two separate viaducts are parallel to each other, composed of simply supported spans with precast prestressed V-shaped cross sections of variable lengths ranging between 24 m and 42 m. The piers consist of octagonal columns founded on bored piles 1.2 m in diameter, driven to dense sand stratum at 28 m depth.

The owner is the Buenos Aires city government. The feasibility studies and original design were carried out by ATEC Ingenieros Consultores, who also acted as project managers. The construction works and detail design were performed by COVIMET (a joint venture between Argentinean and Spanish construction and structural design firms), who began the works as concessionaires responsible for building and managing the toll project for 20 years, until the project was transferred to the government of the city. At present 130,000 vehicles use the highway every day.

3.3.12 La Plata–Buenos Aires Highway over Riachuelo Bridge

The 54 km of the La Plata–Buenos Aires highway connects the capital of the Buenos Aires Province (La Plata) with the city of Buenos Aires (Federal District). It needs to cross the Riachuelo near its flow into the Río de la Plata, where its width increases very much, in a harbor zone. It was necessary to design two identical bridges with severe impositions: a free span not less than 75 m, a vertical clearance for navigation of 27.5 m, an adjusted schedule for construction, and consideration that low construction cost was a decisive variable for alternative selection.

The whole bridge has five spans, with three continuous central spans and two simply supported end spans. Total length is 236.5 m; the central span length is 76.5 m. The superstructure is made of prestressed concrete precast segments of 24 m, and 59 m for the central span. Erected as a gerber beam, the
central and side spans were transformed in a continuous beam with the inclusion of prestressed tendons across the support sections to obtain continuity. The slabs were cast-in-place. Two bridges were built with a 16.9 m width to accommodate traffic in each direction. Piers are reinforced concrete columns with constant sections, cast with traveling forms, joined with a lintel to support the superstructure. The foundation was built with bored, cast-in-place piles 36 m long, to reach a dense sand stratum.

The bridge (Figure 3.15) was designed by the engineers Luis J. Lima, Edgardo L. Lima, R. González Saleme, and C. González Lima (La Plata, Argentina). The design was a simple and economic, easy to build in the imposed time with the disposable technology, and it fulfilled perfectly all the initial imposed conditions. It is adequate for the whole highway project and the surrounding landscape, without lack of measure, pomposity, uselessness, or useless cost enhancement. The owner is DNV and the contractor is a joint venture called COVIARES (Consortio Vial Argentino Español). Construction works began in 1989 and it was opened to traffic in 1991. Piles were done by TREVI Argentina.

3.3.13 New Colastiné Bridge

The greatly increased traffic between the capital cities of the provinces of Entre Ríos and Santa Fe required that the National Route N° 168 be upgraded into a two-lane highway in each direction. It was necessary to build a new bridge over the Colastiné River beside the existing bridge (see Section 3.3.3) to accommodate the new traffic lanes (Figure 3.16).

The new bridge has the same configuration as the old one: 10 spans of 52.3 m. It is composed of a 523 m long, 3 m deep prestressed box beam. The box section has a 12.73 m wide top slab and a 5.2 m wide bottom slab. The substructure is composed of two 2 diameter column-shaft bents, 44 m long. Abutments are of the closed type and founded on five 1.4 m diameter piles. The new design reflects bridge construction technology advances in the country over the last 40 years. At present, the new bridge is in its final construction stage using the incremental launching method.

The bridge was designed by In-Group and engineer Carlos Gerbaudo (Córdoba, Argentina) was the technical project manager. The owner is DNV and the contractor is a joint venture between Superemento SAIC and Jose J. Chediack SA. Construction work began in 2008 and it was opened to traffic in 2011.
3.4 Steel Girder Bridges

3.4.1 La Polvorilla Viaduct

Considered to be one of the most difficult railroads routes in the world, the Huaytiquina Railway, today called Tren a las Nubes (Train to the Clouds), is a train service in Salta Province that links the Argentine northwest with the Chilean border in the Andes mountains. The train track line is 571 km long and at its highest point reaches 4220 m above mean sea level. It is the world’s third highest railway line. Originally built for economic and social reasons, it is now only exploited for tourism due to its heritage value. It includes 11 viaducts, La Polvorilla being the most astonishing of them.

The construction of the railway started in 1921. Its purpose was to serve the borax mines of the area. La Polvorilla viaduct, the highest of the line, was finished on November 7, 1932. The complete railway was opened on February 20, 1948, but it was not until the late 1970s that it became a tourist attraction. The route was laid out by American engineer Richard Fontaine Maury. Located 4220 m (13,845 ft) above sea level, the curved viaduct is 224 m long (7 × 20 m + 6 × 14 m) and 70 m high (Figure 3.17).

The steel needed for the construction came from Cosulich steel mills in Trieste, Italy. All elements of the structure were shipped to Buenos Aires Harbor and transported by land (1500 km), to the construction site. León Gubbioni was site manager. The owner was Ferrocarriles del Estado but nowadays it is managed by a private concessionaire for tourism exploitation. During the construction, three workmen lost their lives.

3.5 Arch Bridges

3.5.1 Quequén Salado Bridge

This roadway bridge (Figure 3.18) was built over the Quequén Salado River. It is part of the route that links the villages of Oriente and Copetonas, located at the south of Buenos Aires Province. Taking into consideration the depth and width of the river and water flow conditions at the site, the most suitable
design was a bridge without intermediate piers, which led to the construction of an arch-type bridge. It has the unusual characteristic that the arch rib cross section is a reinforced concrete folded plate 0.25 m thick, 1.75 m deep at supports, 1.5 m at the crown, and 7 m wide. The bridge’s span is 60 m, with a rise of 9 m. Spandrel spans are spaced every 5 m. The deck is a 0.22 m thick folded shell. The road width is 8.3 m with two sidewalks 1.2 m wide on both sides.

It was designed by the Bridge Division of Dirección Provincial de Vialidad de Buenos Aires, who are also the owners. Construction work began in 1961 by the contractor CODI SA. The bridge was opened to traffic in 1964.

### 3.5.2 San Francisco Bridge

This bridge (Figure 3.19) was built on Route 5 over the San Francisco River, linking the cities of Las Lumbreras and Pichanal in the province of Salta. The total length of the bridge is 720 m, composed of 12 equal spans of 60 m each. Each span is a tied arch with the deck acting as a tension chord. The use of prestress on the deck’s girder beams and the prefabrication of the prestressed hanger resulted
in a high-stiffness structure with well-distributed flexural moments in the arch under the action of partial live loads. It was a great innovation at the time it was built. After many years of service, there was a collapse in one of the spans. After that, all arches were reinforced with tensors, as seen in Figure 3.19.

The superstructure is pairs of hollow frustums cones linked at natural terrain level by beams, which provide great stability to the system against overturning induced by earthquake loads. The piers are cylinder shaped and founded 18 m deep. A cylindrical cofferdam with concrete sheet piles was used, which allowed the drainage of the excavation and remained as lost formwork. Construction work began in 1964 by owner Dirección Provincial de Vialidad de Salta. Contractors were Roffo, Irisiso y Cía. The bridge was opened to traffic in 1972.

3.6 Truss Bridges

3.6.1 Dulce River Bridge

The first studies for the construction of this railroad and roadway bridge began in 1880, but it was not until 1924 that works began. It was considered an important and very costly construction work for the country during that period. The structure was designed for dual purposes: railroad and roadway traffic. The bridge (Figure 3.20) is 840 m (12 × 70 m) total length. It spans the Dulce River in Santiago del Estero Province and links the cities of La Banda and Santiago del Estero. It is located near the latter, which is the oldest city in the country, founded in 1550 by Spanish colonizers.

It was designed by engineer Pedro Mendiondo and contractor was Baglioto, Binda y Cía. Steel trusses (6400 tons) were built by Gutehoffnuagshüte (Ruhr, Germany). In October 1927, after load testing by utilizing a cargo train, it was opened to the public. Each 70 m span has two truss beams built 11 m apart. The original design comprised 6.7 m width for the roadway and 3 m width for the tracks and sidewalks. In 1950 a bicycle lane of 1.5 m was added.

The piers are composed of three cylindrical caissons linked by a lintel to support the spans.
There are two curious legends about the construction of this bridge. One is that all the steel needed for the bridge was given by Germany to Argentina free of charge as a compensation for the sinking of three Argentinean cargo vessels, Toro, Monte Protegido, and Oriana, by German submarines in the Atlantic Ocean during World War I in 1917. The other myth tells us that there is a solid gold rivet placed somewhere among the thousands of the structure. Yet nowadays, one can seldom see people searching for said rivet.

### 3.6.2 Superí and Zapiola Streets Bridges

The existing superstructures (Figure 3.21a) were six continuous 18 m long prestressed concrete spans over an important expressway in Buenos Aires. The cross section was transversely prestressed. The piers are solid wall type. Both bridges were built in 1969. To relieve traffic congestion of more than 250,000 ADT, the expressway was widened in 2001. Three exiting central columns of two continuous prestressed concrete overpasses bridges, of six spans each, were removed. At least four lanes were kept open to traffic in each direction, at all stages of the construction work. Different structural solutions were analyzed, but finally, one named “the hanger” was adopted. Rectangular steel tubes were chosen for the truss elements cross sections. An orthotropic steel deck supports the roadway surface and acts at the same time as the tension chord of the main truss from which the old structure was hanged.

The Superí Street Bridge (Figure 3.21b), the largest one, is composed by two truss beams 41.11 m long and 6.8 m high. Two transversal beams link both trusses at the upper vertex to avoid lateral buckling. The completed structure can be considered as two superimposed systems. The first is the prestressed concrete continuous beam of six spans, with its three central spans elastically supported by the new structure. The second is the new structure, the simply supported steel truss from which the existing concrete deck is suspended. The old deck was suspended by high-strength steel bars.

The two bridges were constructed between January 2001 and April 2002, leaving four lanes of the expressway opened to traffic permanently during the works. The bridge was designed by Del Carril–Fontán Balestra y Asoc. (Buenos Aires, Argentina). The contractor was AUSOL SA (Autopistas del Sol). The project was awarded the national structural engineering prize Ing. José Luis Delpini.
3.7 Cable-Stayed Bridges

3.7.1 General Belgrano Bridge

This was the first bridge built over the Paraná River and the second physical connection between the Mesopotamian region and the rest of the country. This roadway bridge links Resistencia, capital of the Chaco Province, with the city of Corrientes, capital of the province of the same name. Due to the fact that in the 1960s the only existing link to the Mesopotamian region was a tunnel that wouldn’t allow transit of cattle or fuel across the Paraná River, the bridge was very important for the three provinces of the region, which are enclosed by the Paraná and Uruguay rivers and isolated from the rest of the country. A new bridge would also serve international communications with two neighboring countries, Paraguay and Brazil.
The project includes a cable-stayed bridge and two approach viaducts: one on the Chaco side on National Route 16 and another one on the Corrientes side on National Route 12 (Figure 3.22). Those structures are 2000 m long (1666 m over water) and 8.3 m wide, with one lane in each direction. The vertical navigation clearance is 35 m. The required horizontal clearance is 200 m. The cable-stayed bridge comprises three spans (163 m + 245 m + 163 m). It is composed of two 225 m long suspended structures, placed symmetrically along the main pylons axes, which are 245 m apart. A simply supported span of 20 m links these two structures to form the main span of 245 m. This suspended span reduces the effect of deflections on the two main structures. Each main pylon is a W-shaped frame that rests on a pile cap for its foundation. A set of eight stays completes each main 83 m high pylon.

The cross section is a two-box girder. The deck is completed with precast transverse slabs, 6.9 m long and 2 m wide, supported on the main beams. When the deck was finished, the transverse beams were prestressed. The original stays were of the locked coil type, but they had to be replaced after 25 years of service. The longitudinal beams of 3.5 m deep were prestressed. The approach viaducts over the river are composed of nine spans of 82.6 m each on the Chaco side, and three spans of 82.6 m each on the Corrientes side. They were built by the balanced cantilever method with precast segments 4.1 m long and 2 m deep at center span and 4.5 m deep over the supports. The overall deck width is 11.3 m, carrying two 3.65 m wide lanes, narrow emergency shoulders of 0.50 m and pedestrian sidewalks 1.5 m wide. The piers of the approach viaducts are constant deep box sections and were built by the sliding formwork method. The foundations were made using 1.8 m diameter bored piles with variable lengths between 38 m and 60 m, and with preloading cells, they are clamped by penetration into the hard clay stratum.

At around 20 years of service, the replacement of all the stays was required. Construction works were carried out by Freyssinet SA (Spain) in 1995. Parallel strands stays were installed. The link between both cities, with only two lanes, has proven to be insufficient for the traffic, which has been ever-growing since its construction. The construction of a new bridge is now under consideration.

Construction work began in August of 1968 by the initiative of the governments of the provinces involved: Corrientes, Chaco, and Formosa. The owner was DNV, who called for international bids in 1965. It was designed by Professor Jean Courbon from the Société D’Études et D’Équipements D’Entreprises de Paris, France. The contractor was a joint venture between Ferrocemento SPA (Rome, Italy), Umberto Girola (Milan, Italy), Impresit (Salerno, Italy), and Sideco SACIC (Buenos Aires, Argentina). The bridge was opened to traffic in May 1973.
3.7.2 Zárate–Brazo Largo Bridges

The Zárate–Brazo Largo Bridges link the north of Buenos Aires Province and the south of the Mesopotamian region. Placed nearly 80 km away from Buenos Aires, they are of paramount importance for the transportation system of the country. The bridges comprise a 13 km highway that crosses over two branches of the Paraná River: Paraná de las Palmas and Paraná Guazú. They link the city of Zárate and a place called Brazo Largo. Between the branches, which are navigable by Panamax vessels, there is an island called Talavera.

Two bridges were built over the respective branches. Both structures serve a dual purpose: roadway and railway traffic. The latter was very challenging for structural designers due to the asymmetrically loaded deck, because there had never been a cable-stayed bridge with asymmetric loads. The original design was created by the famous Italian professor Ricardo Morandi in 1966, but the owner, DNV, finally awarded the detail engineering contract to joint venture TECHINT–Albano SA in December of 1970. The original design of the two main cable-stayed bridges was reformulated by the contractors under the supervision of Leonhardt, Andra & Partners (Stuttgart, Germany) and Fabrizio de Miranda (Milan, Italy). Only minor adaptations were introduced to the railway and roadway approach viaducts, but the two cable-stayed main structures were redesigned. The original design comprised two separate decks for railway below and for roadway in the upper part. The new design modified this criteria and placed a unique deck with the rails at the side of the railroad, thus introducing strong asymmetry in the load path.

The main bridges (Figure 3.23) are cable stayed with an overall length of 550 m (110 m + 330 m + 110 m). Navigational clearance is 50 m high, allowing the navigation of Panamax vessels. Two external high-strength welded steel orthotropic box beams are linked together by truss girder beams in the transverse direction. The asymmetrical 22.6 m wide structure has the following configuration: a four-lane roadway with 1.3 m external sidewalks, a median of 0.50 m that separates two lanes in each direction, and the remaining 4.5 m to accommodate the railway track. This asymmetry is also reflected in the stays configuration: two stays for every position on the railway side and only one for the roadway side.

Pylons are H-shaped frames with hollow concrete columns 130 m tall. A transverse beam at middle height is used to support the main steel beams and a steel X links both columns at the top.

The structure rests on bored piles of 2 m diameter with variable lengths between 30 and 70 m. Some of the piles were driven 30 m deep into the river. All of them have preloaded cells.

The original stays were parallel 7 mm diameter bars, but had to be replaced after 20 years of service. The new stays, which are at present being installed by Freyssinet SA (Spain), consist of parallel strands.
Approach viaducts for roadway and railway traffic are quite similar in their structural configuration, but differ in dimensions and alignment.

Construction work began in November 1971 and the first bridge, over Paraná de las Palmas branch, was opened to traffic in February 1977, while the second, over the Paraná Guazú branch, was opened to traffic in November 1977. This project broke many records when completed. The bridge had the world’s longest cable-stayed span for dual-purpose traffic and the first with an asymmetrically loaded deck. Its design and construction were a real challenge for engineers. It is still the country’s longest cable-stayed span.

### 3.7.3 San Roque González de la Cruz Bridge

This bridge (Figure 3.24) connects the city of Posadas (Misiones, Argentina) with Encarnación (Paraguay), across the Paraná River, a natural boundary between northern Argentina and southern Paraguay. Its structure comprises a cable-stayed bridge with two approach viaducts. Its function is to serve international railway and roadway traffic.

The main structure comprises a three-span cable-stayed bridge (115 m + 300 m + 115 m), and a superstructure of a three-cell prestressed concrete box girder 19 m wide and 3 m high, providing high torsional stiffness to resist the highly asymmetric railway loads. The vertical clearance, once the Yacyretá Dam is completed, will be 18 m, which is considered to be sufficient for navigation purposes on that section of the river. The method of balanced cantilever with precast segments 10 m long was used. The foundations of the pylons are cylindrical caissons driven to the sound basaltic rock.

Four other structures in the project include a continuous slab for the roadway approach viaduct on the Argentinean shore, of 112 m (20 m + 3 × 24 m + 20 m), built over land; a 520 m (26 × 20 m) railway approach viaduct, also built over land; an Argentinean approach viaduct of 1505 m (29 × 55 m), built utilizing sliding formwork; and the Paraguayan approach viaduct of 385 m (7 × 55 m), built by the launching method for the first time in the country.

The bridge was structurally designed by joint venture COPPEN integrated by Cabiholsky-Hechausen, CONSULAR, CADIA, and Becerra Ferrer-Lange (all from Argentina), and Leonhardt.
(Stuttgart, Germany) was consulting engineer. The owner is DNV. The bridge was built by a joint venture between the Argentinian construction firms Sideco Americana, EACA, and Girola between December 1980 and 1988. Construction work suffered many interruptions due to several reasons, among them the extraordinary floods of the Paraná River in 1982 and 1983, the Malvinas War, and Argentina’s economic crisis with hyperinflation, which produced restrictions on the importation of the necessary elements for the bridge. The bridge won the International Prize Puente de Alcántara awarded by Fundación San Benito de Alcántara (Spain).

3.7.4 Nuestra Señora del Rosario Bridge

This cable-stayed bridge (Figure 3.25) is the main connection between the cities of Rosario (Santa Fe Province) and Victoria (Entre Ríos Province) crossing the Paraná River and its floodable plains. The whole project covers an extension of 59.4 km and is composed of various bridges over the flood areas, with an accumulated length of 8.1 km, and a main structure that crosses the Paraná River and is 3.49 km long. This structure is composed of a cable-stayed bridge 608 m long (124 m + 350 m + 124 m), which spans the navigation channel with a vertical clearance of 50 m, a 1130 m approach viaduct on the Rosario side, and a 2380 m approach viaduct on the Victoria side.

Pylons are H-shaped frames. The prestressed concrete superstructure is pi-shaped. It was built by the balanced cantilever cast-in-place method. Its segments are 10.4 m long. The deck is 11.3 m wide, with two lanes of 3.65 m, narrow emergency shoulders of 0.50 m, and pedestrian sidewalks 1.5 m wide.

Construction began in 1998, but was repeatedly interrupted due to lack of funding. It was opened to traffic in May 2003. Construction works were carried out by a joint venture Puentes del Litoral SA integrated by IMPREGILO SPA (Italy), YGLIS SA (Italy), HOCHTIEF AG (Germany), Benito Rogio e Hijos, SIDECO-IECSA (Argentina), and TECHINT (Argentina). The main bridge was designed by Leonhardt & Andrä und Partner GmbH. This is the lastest bridge built over the Paraná River.

![FIGURE 3.25](See color insert.) The Nuestra Señora del Rosario Bridge, viewed from the Rosario side. Protections against vessel collisions can be seen.
3.8 Suspension Bridges

3.8.1 Marcial Candioti Bridge

This bridge (Figure 3.26), located north of Santa Fe Province on National Route 168, spans Setubal Lake. It is an important cultural heritage symbol. It was built in the early 1920s and was opened to traffic in 1928. The main purpose of the bridge was to support an aqueduct, which used to be supported by two bridges that collapsed due to various reasons in 1904 and 1920.

The owner, Obras Sanitarias de la Nación, assigned the design to Casa Wattinne Bossut et Fils, who represented the Societe des Chantiers et Ateliers de la Gironde (Paris, France), who built all the parts of the bridge with the collaboration of the prestigious engineer M. G. Leinekuge. The design follows the system created by a lieutenant colonel of the French Army, Albert Gisclard, which consists in a configuration of nondeformable cable triangles and results in a very stiff structure. Additionally, the designer has added an Ordish suspension system to avoid the nonlinear deformation of the main cables. By applying this system, compression on the stiffness beam is not introduced.

The bridge has a total length of 295.26 m (73.88 m + 147.7 m + 73.88 m), and support an aqueduct and a 6 m wide deck for roadway transit. It rests on large piers founded on piles of nearly 12 m diameter. At the time of its construction it became an emblem of the city of Santa Fe. In 1973, 100 m downstream, the new Nicasio Oroño Bridge (see Section 3.3.4) was opened to traffic, so only pedestrian traffic was allowed on the old suspension bridge, which still remained as an icon.

The bridge almost collapsed due to the scouring of the foundation of one of the main towers in a significant flood. The bridge remained semi-sunk between the years 1983 and 2000. City authorities called for bids for its reconstruction in 1988. The contractor Concesiones y Construcciones de Infraestructura (CCI) was assigned the job. EEPP (Estudio Estructural Polimeni Perez y Asoc.) were the structural designers. It was imperative to maintain the original appearance of the bridge. The replacement tower was manufactured in the Ferma Shop (Esperanza, Santa Fe) and had to be placed 6 m from the original location. Thus, the bridge was forced to increase its main span, reaching 153.7 m long, and decrease the east span to 67.65 m. The retrofitted bridge was opened to traffic in 2002.

3.8.2 Hipólito Irigoyen Bridge

This self-anchored suspension bridge (Figure 3.27), one of the two only bridges of this type built in the country, spans Quequén River and links Necochea city to the Quequén beaches on the Atlantic Ocean,
south of Buenos Aires Province. The total length is 270 m. The central span is 150 m with two side spans of 60 m. Pylons are 26 m tall. The bridge is self anchored. This technique was not very common around the world, due to the fact that it doesn’t apply to long-span bridges. The stiffening beams are 8.8 m apart from each other and the deck has a 6 m roadway width and two 1 m wide sidewalks per side. This bridge has a better-known twin brother, the Chelsea Bridge in London. The structure elements were provided by the Chantiers et Ateliers de la Gironde, France, who also provided the materials for the other suspended bridge (see Section 3.8.1)

The bridge is a milestone for a self-anchored suspension bridge. When it was inaugurated only a few bridges of this type existed worldwide: one over the Rhine, opposite Cologne and three others over the Alleghany River in Pittsburgh, Pennsylvania in the United States. It was built by contractor Weyss & Freytagg (Germany), by commission of the owner, the Bridge and Roads Department of Buenos Aires Province, in 1928.

3.9 Movable Bridges

3.9.1 Old Pueyrredón Bridge

The Old Pueyrredón double-leaf bascule bridge (Figure 3.28) crosses the Riachuelo River. The total length of the bridge is 88.8 m. The center span is a double-leaf bascule of 38 m (two cantilever spans of 19 m), and the fixed spans are 25.4 m long. The original overall width was 12 m with two lanes of 3 m and two 3 m sidewalks. In 1931 the mechanical system failed and the bridge remained fixed in its closed position. It was widened in 1958, but in 1970 it was closed to traffic due to safety reasons. It was saved from dismantlement when city government designated it a Historic Landmark. After that, it was reopened for light vehicles. The bridge location was previously occupied by six other bridges since the
The first wooden bridge over the Riachuelo River was built in 1791. Some of them collapsed and others were replaced when new technology rendered them obsolete.

The bridge was built between 1925 and 1931. The onsite contractor was Dickeroff & Widmann SA. Steel members were manufactured in Oberhausen (Germany) by Gutehofnunghütte, who also designed and provided the mechanical parts for the movable span. The bridge was completely retrofitted in 2008. New mechanisms were installed and a new strengthened metallic structure was designed by EEPP (Estudio Estructural Polimeni Perez, Buenos Aires, Argentina), who were also site supervisors. The main contractor for the retrofitting was DALCO SA–EMA SA UTE. The retrofitted bridge was inaugurated on January 2010.

### 3.9.2 Alsina Bridge

This 72-year-old bridge (Figure 3.29) spans the Riachuelo River, connecting Nueva Pompeya neighborhood of Buenos Aires City Federal District with Valentín Alsina, a neighborhood of Lanús (Buenos Aires Province). It is a movable bascule bridge, which allows navigation traffic through the Riachuelo River, in La Boca neighborhood, one of the city’s main tourist attractions at present.

The total length of the bridge is 173.16 m, composed by two fixed spans of 65.33 m and a bascule span of 42.5 m. The total width is 24 m, accommodating a roadway 18 m wide and two sidewalks 3 m meters wide on each side. The bridge crosses the navigation channel with a skew angle of 64 degrees. On both ends of the bridge, great portals were built, in colonial style, where policemen had guard precincts.

The bridge was designed by engineer José María Páez and construction took six years, between 1932 and 1938. Foundations, piers, and abutments were designed by Parodi and Figini. The metallic trusses and the bascule mechanism were manufactured in Hannover (Germany) by Louis Eilers. The owner is the Buenos Aires city government.

### 3.9.3 Nicolás Avellaneda Bridge

This magnificent movable lifting bridge (Figure 3.30), built in 1937, spans the Riachuelo River and connects Maciel Island with Buenos Aires City Federal District. It allows navigation of vessels up to 21 m high when closed, and up to 43 m when open. The lifting operation required 3 minutes and served the vehicle traffic flow very well in those days. Vessels demanded its lifting three times a day. At present, the
The main bridge is a high-strength steel structure composed by two towers and a lifting span of 65 m. The roadway width is 12 m, accommodating two 3 m wide lanes in each direction. The project includes two approach viaducts with 1633 m total length. The lifting of the main span requires two 230 ton counterweights and four chains powered by two 55 HP electric engines. Foundations required the use of pneumatic caissons 20 m deep, resting on dense sand stratum.

The owner is DNV. Construction work began in 1937 and the bridge was opened to traffic in 1940. Engineer Juan Agustín Valle and architect Eduardo Rodríguez Videla were the architectonic designers.
3.10 Pedestrian Bridges

3.10.1 Puente del Sesquicentenario Bridge

This pedestrian bridge was built over Figueroa Alcorta Ave. for the sesquicentennial commemoration of the first revolt against the Spanish Crown (May 25, 1810), as part of the great exposition held in the parks north of Buenos Aires. It was demolished in 1974 to leave room for a large monument called Altar de la Patria, which was never completed. Finally, a concrete bridge was rebuilt almost 100 m away from its original position, using the original drawings. This elegant arch was designed by engineer Atilio Gallo and architect César Jannello. The owner is the Buenos Aires city government.

Its cross section is composed of a parabola on the underside and a horizontal surface on the top, extruded on a 50 m long circular arch path. Its gradient is 15% to allow for easy pedestrian transit. The arch depth is 50 cm at the center. The deck is 10 m wide. The cross section is composed of three hollow cells with the exception of the central 10 m, where the deck is solid. Two tendons are anchored at ends of the arch. The vertical reactions are transmitted to a spread footing through neoprene bearing pads.

The first construction was carried out by Bava, Seery, and Litmayer (Bs. As., Argentina) and the second by Hindoust–Klein (Bs. As., Argentina) (Figure 3.31). The footbridge is a city monument and provides service to many students who attend the law school of Buenos Aires University.

3.10.2 Kuñataí Bridge

This pedestrian bridge (Figure 3.32) crosses above National Route 12 in the city of Posadas, Province of Misiones. The superstructure, a prestressed precast trapezoidal box beam 25 m long, is supported by two helical staircases, which act at the same time as piers. It is actually a unique curved beam with a total length of 60 m, but due to its shape, the maximum flexural moments are almost identical to a simply supported beam of 25 m. After all main beams were erected, the whole structure was prestressed together. The width of the staircase and walkway is 2.4 m. The cross-sectional depth is variable between 0.60 m, at the center, and 1.1 m at the supports. The foundations required the installation of prestressed anchorages into the rock to guarantee stability.

The bridge was built by SETA Hidrovial SRL (Rosario, Argentina) in 1988. Professor Dante Seta was its designer and construction supervisor. Although it isn’t a large structure, construction had some complexities and the finished structure is really impressive. Locals call it the “unsupported bridge.”
3.10.3 Puente de la Mujer Bridge

The old port of Buenos Aires has recently been urbanized with high-quality residential buildings, hotels, and pedestrian walkways. The real estate development is managed by Corporación Antiguo Puerto Madero. Within this large area, a subzone named Dock 3 was assigned to real estate developer Emprendimientos Inmobiliarios Arenales SA who, in turn, hired architect and engineer Santiago Calatrava (Spain) to design an iconic pedestrian bridge (Figure 3.33). It was Calatrava’s first assignment in Latin America. He designed a movable steel cable-stayed bridge, which allows navigation traffic by rotating around its pier. The bridge has an overall length of 160 m. Its span arrangement comprises a 90 m central pivoting span, of which 70 m are stayed and the remaining 20 m act as a counterweight on the opposite side of the pylon, and two fixed spans. The deck width is variable, reaching 6.2 m. The superstructure is composed of a steel box beam. It is hollow at the central span of the bridge, but filled using high-density concrete and steel shots at the counterweight span. The pylon is inclined and 67 m high. Stays are parallel strands.

The creator said that he conceived this bridge-sculpture inspired by a couple dancing the tango, a popular music genre originated in the Río de La Plata region and which has become an emblem of Buenos Aires. The bridge was built by URSSA, who manufactured the steel structure at a mill in Bilbao (Spain). Contractor Trevi was in charge of foundations, using bored piles 1.2 m diameter and 26 m deep to reach a dense sand stratum. Manessman–Dematic–Demag (Germany) provided the mechanical parts. The site contractor was Brambles (Lastra, Spain).

3.10.4 Balconies Iguazú Footbridges

Iguazú Falls was declared a World Heritage Site by UNESCO in 1984. These bridges consist of the Upper, Lower, and Garganta del Diablo footbridges. They are located on the Iguazú River, which is a natural boundary between Argentina and Brazil, and are visited by thousands of tourists every year. They are within the Iguazú National Park. The Iguazú River flows through a smooth topography until it reaches a series of faults and rapidly descends into an 80 m high canyon in La Garganta del Diablo, where the water produces a thundering sound and an astonishing spectacle. There are more than 270 falls in the area, where cliffs and islets are scattered in a half-moon shape. There are three basic circuits for visiting the falls: an upper path, a lower path, and Garganta del Diablo path (Figure 3.34), all with several balconies to appreciate the beautiful landscape. The total length of the three circuits is approximately 3 km.

The owner is the National Parks Administration, and the manager is the Concessionaire Iguazu Argentina SA (Carlos E. Enríquez and Partners, Posadas, Argentina). Pedestrian walkways of 3 km
total length were designed by Del Carril-Fontan Balestra Engineers (Buenos Aires, Argentina) and construction works were carried out by Albano Construcciones (Buenos Aires, Argentina). The footbridges were built on piles embedded and anchored in the rock (basalt), the deck is 50 cm above ground level and built with grating to allow free movement of animals and the access of sunlight to the flora growing under them. The footbridges are 1.2 m wide and are designed to be circulated in one way, so that thousands of tourists may walk the circuits without interfering with each other. They have no stairs or steep slopes in order to allow easy movement of handicapped people.
The structures consist of a succession of 6 m, 9 m, and 12 m long metal spans, with two rolled steel beams and transverse grating plates. The deck of the walkways are placed 60 cm high with respect to the natural soil, so that small animals, snakes, and insects can live without disruption of their environment. Also, the grating used in the floor allows natural sunlight to reach the soils for the benefit of the flora. For the comfort and safety of children and handicapped people, the railings have two handrails at different heights.

Railings can be folded over the deck in case of a large flood, offering low resistance to the water passing over the bridges. In case of a very large flow, the bearings are designed to act as fuses, letting the spans be carried away by the water and leaving the foundations undamaged. This design was based on experience with the two previous walkways, which were destroyed by floods since parts of the foundations remained scattered across the landscape, causing a high environmental impact before and during their demolition. Since they have been in service, several spans of the walkways have twice been washed away by floodwaters, demonstrating the correct performance of the above-mentioned fuses, and the infrastructure remained in perfect condition. As the concessionaire has spans stored in his warehouses, the lost ones may be replaced in a few hours after the flood ends. As it is a highly ecologically driven project, flora and fauna were taken into account in the plan. Several pillars had to be moved a few feet away from the original plan in order to not disturb an alligator den or avoid destroying an important plant.

3.10.5 Dorrego Ave. Pedestrian Bridge

In 2008, the Buenos Aires city government called for bids a pedestrian bridge. The Dorrego Ave. Pedestrian Bridge is located in a high-density forested area of the city, where it is common to see people jogging or practicing various sports during the day (Figure 3.35). The recently inaugurated bridge still had no official name at the publication of this book. It is said that this bridge will be named Puente de Miguel (Miguel’s Bridge) after a handicapped person who is very much admired by the locals for his striving to achieve, day by day, personal improvement.

The bridge is cable stayed. Its total length is 165.76 m, composed by a main bridge with a central span 49.14 m long, two side spans 36.47 m long, and completed with two simply supported approach spans.
of 21.84 m. The pedestrian walkway width is 3 m. The composite superstructure comprises a steel trapezoidal box beam 0.50 m deep and a concrete slab 0.12 m thick. Its two main towers are 17 m high and the foundations are 0.50 m diameter, 15 m deep bored piles. The maximum grade is 7% and the vehicle clearance is 4.95 m in the center and 4.43 m at the ends.

Structural designers were EEPP (Estudio Estructural Polimeni Perez) and the main contractor was Andersch Ingeniería SRL.

### 3.11 Special Bridges

#### 3.11.1 Futaleufú Pipe Bridge

The Futaleufú Pipe Bridge (Figure 3.36) is part of the adduction system for the Futaleufú Hydroelectric Plant. The purpose of this special bridge is to carry a 7.7 m diameter pressurized pipe over very low-support-value soil over a deep valley. As a result of the analysis of many alternatives, a solution was adopted taking into consideration the short schedule for the project and unexpected risks from the construction process.

The total length of the bridge is 260 m (60 m + 7.8 m + 62.2 m + 62.2 m + 7.8 m + 60 m) composed of a central continuous beam and two simply supported spans 60 m long. The main structure is composed by a centrally located pylon and two pairs of rigid stays separated longitudinally at 124.4 m, leaving a 7.8 m long cantilever beam in each side that supports the simply supported side spans. The central span is composed of two pairs of reinforced concrete 7 m deep I-beams placed at the sides. This pairs of beams are separated 12.5 m and are transversally stiffened with diaphragms in correspondence with the steel pipe supports. Side spans are composed of two reinforced concrete beams 7 m deep, 7.2 m wide, box sections.

The main pylon is 44.3 m high and founded on a 16 m diameter, 1.2 m thick, and 31 m deep cylindrical caisson.

An exigent deflection limitation of the steel pipe had to be taken into account for the design of this special bridge. This rendered the project very expensive due to the fact it had to be done with high-strength
steel that was not manufactured in Argentina. Another unusual condition was the high percentage of live loads, reaching up to 50% of the total load. This condition lead to the design of rigid stays instead of cables.

The owner, Agua y Energía Eléctrica, built this project between 1971 and 1978. The bridge was designed by engineer Ricardo Wagner of Tecnoproyectos Consultora (Buenos Aires, Argentina), who was also technical project manager. The contractors were a joint venture between EACA and Panedile (both from Buenos Aires, Argentina). The firm Prentesac SA (Buenos Aires, Argentina) was in charge of detail engineering design and all of the prestressed operations were made by said firm with Carlos Heckhausen (Argentina) as a consulting engineer.

### 3.11.2 Cangrejillo Creek Pipeline Bridge

This bridge (Figure 3.37) was built over the Cangrejillo Creek in Catamarca Province in northwest Argentina. Its main purpose is to carry a copper concentrate pipe 0.20 m in diameter and a 1 m footpath for maintenance of the facility. The bridge will serve the transit of gold and copper through the pipe, which will connect a mine located to the north of Andalgalá with a rail facility in San Miguel de Tucumán. It spans 337 m over a 90 m deep valley. It is a cable suspension structure that supports an open steel deck frame. Catenary’s cables sag 7.85 m at midspan.

The main structure is composed of two pairs of cables anchored in reinforced concrete abutments and will allow the future transit of a 2 ton truck, and it has a 3 m wide deck. The abutments provide a secure anchorage of the cables to the rock by means of a concrete block that is fixed to the side of the mountain with a system of 24 and 28 post-tensioned rock anchors. Each anchor is a 15 mm strand, 30 m to 60 m long, installed with a 45-degree slope.

As the bridge is placed in a highly seismic region, it was designed according to AASHTO standards and IMPRES-CIRSOC (Argentine standards for earthquake-resistant structures). This type of structure was considered the best alternative to a buried pipe and road, which would have produced a high environmental impact on the waterfalls and rainforest valley. The owner is Minera Alumbrera, and it was designed by OPAC Consulting Engineers Inc. (United States) and built by Albano Construcciones. It was opened to service in October 1998.
3.12 Future Bridges

3.12.1 Reconquista–Goya Bridge

The road between the cities of Reconquista (Santa Fe Province) and Goya (Corrientes Province) is an important 42 km long project that crosses the Paraná River and its flood areas. This project required 16 bridges on the plateau and a main structure 4 km long to cross the Paraná River. This structure consists of a main cable-stayed bridge (Figure 3.38) over the navigation channel and two approach viaducts. The main bridge has a total length of 930 m with a five-span continuous prestressed concrete beam (90 m + 180 m + 390 m + 180 m + 90 m), trapezoidal box-type section 4.5 m deep. Its three central spans are supported by a set of stays arranged in a single plane along the longitudinal axis of the bridge.

A striking feature of this design is that it comprises five continuous spans instead of the conventional three spans common in such structures. This scheme reduces the tension force in the first pile next to the pylon. Furthermore, it decreases rotations at the junction with the viaducts. The deck has an overall width of 21.7 m, accommodating two lanes 8.3 m wide in each direction, a 2 m median, New Jersey type transit barriers, and two sidewalks of 1.5 m per side.

There are two different types of approach viaducts to the east and west, with six spans of 90 m, and low viaducts. Among the latter, the one on the west bank is a 1500 m structure composed by 60 m continuous spans. Its trapezoidal box-type cross section is similar to the one used on the main bridge. The east side low viaduct is a conventional structure of 35 m long precast prestressed beams to complete a structure of 245 m.

The project was developed by a joint venture between some of the most important consulting firms of the country: Consular, IATASA, ATEC, Oscar Grimaux y Asoc., and INCOCIV. The main bridge was designed by ATEC, COPIGA, and Del Carril–Fontán Balestra y Asoc. with the advising of Leonhardt, Andrä, und Partners (Germany) as consulting engineers and responsible for the preliminary designs and evaluation of alternatives for the structure of the Paraná River crossing. The approach viaducts and the bridges in the plateau were designed by these firms.

![FIGURE 3.38](image-url) A rendered image of the future Reconquista–Goya main bridge.
The tenders of the bridge are the country’s largest and are now complete. Its construction will require approximately 4 years. It is of vital importance for communication between the Mesopotamian region and the rest of the country and an important route of the Mercosur.

### 3.12.2 Buenos Aires–Colonia Bridge

The Buenos Aires–Colonia Bridge project was designed to provide a permanent link between Argentina and Uruguay, over the Río de la Plata River, a wide estuary formed by the junction of the Paraná and Uruguay Rivers. The governments of the two countries signed an agreement in 1996 that created the Binational Bridge Commission of Buenos Aires–Colonia to manage the project.

The bridge will join the city of Punta Lara, 40 km to the south of Buenos Aires, to a point 8 km away from Colonia in Uruguay. This location was considered the best alternative after the economic evaluation and environmental impact studies made by Louis Berger (leader of the consortium and engineering); Bear, Stearns & Co. Inc. (investment bank); and Latham & Watkins (law firm), who were given the ACEC (American Consulting Engineers Council) excellence award in Washington in 1988 for this study. The results also indicated that the construction of the bridge would result in a significant economic benefit for both countries. It was planned to involve a private partner for design, construction, operation, and maintenance, and the governments of Argentina and Uruguay would provide supporting roles.

Once the bridge is finished, with a total length of 42 km, it will be the longest bridge in the world. It includes access viaducts with spans of 40 m and 8 m over the highest water level, approach viaducts with spans of 100 m, three secondary bridges with main spans of 200 m, and vertical clearance of 32 m and a main cable-stayed bridge over the navigation dredged channel with a main span of 500 m and 65 m of vertical clearance. The decks will include a total of four lanes, shoulders, pedestrian corridors, and a New Jersey barrier, which add up to a total width of 20 m (Figure 3.39).

The project has a significant geopolitical importance for the integration of Uruguay and Argentina and will boost trade between Brazil, Uruguay, Argentina, and Chile. For economic and political reasons the construction of the project has been delayed. The parliament of Uruguay has approved the project but Argentina has not, perhaps because the country has other priorities. The internal rate of return still

![Buenos Aires–Colonia Bridge overview.](image)
3.12.3 Santa Fe–Paraná Bridge

Since 1969, the vital connection between the capital cities of the provinces of Santa Fe (Santa Fe) and Entre Ríos (Paraná) has been made by the Hernandarias subfluvial tunnel. It goes under the Paraná River, with a length of 3.6 km. It was great engineering accomplishment in its time but today is obsolete due to the fact that it has only one lane in each direction. Furthermore, fuel and livestock truck traffic is not allowed.

Due to the permanent growth of the surrounding areas, the deceased civil engineer Alejandro Vega proposed, through the Colegio de Profesionales de la Ingeniería Civil de la Provincia de Entre Ríos, the construction of a new bridge over the Paraná River. At present, feasibility studies have been completed, and the decision to build a new link between cities has been made by the government authorities. The new structure (Figure 3.40) will have a total length of 3.3 km, including a main 700 m cable-stayed bridge over the navigation channel and 2.6 km of approach viaducts. In 2011 tender engineering began for this fundamental new bridge for the integration of the Mesopotamian region and Mercosur countries, but has since been postponed.

3.13 Natural Bridges

3.13.1 Puente del Inca

The Puente del Inca Bridge is located on the eastern slopes of the High Andes, over the Las Cuevas Valley. Horizontal layers of carbonate ferruginous deposits from springs between rock formations were carved by the Las Cuevas River, forming a large natural arch. The arch (Figure 3.41) is 40 m long, 15 m wide, and has a rise of 20 m. It has variable thickness of between 5 and 8 m. It is located 2720 m above sea level. This type of natural arch can generally be found in mountainous or sea coast regions. Several of them are known, both in Argentina and elsewhere. However, the Puente del Inca Bridge stands out among others due to the fact that the smoothness of its shape seems to have been made by man, and the
horizontal road over it that was used by habitants of the area until recent years. It is a unique geological wonder, declared a Natural Monument. To take advantage of the hot springs, in 1925 a luxury hotel was built that was unfortunately destroyed by a devastating flood in 1965. At present, the site is still an important tourist attraction.

3.14 Bridge Management Systems

During the last 6 years, the DNV has been developing a Bridge Management System (BMS) called SIGMA Puentes. At present, there is a limited inventory of bridges in the primary network. Only a few of them were qualified according to their conditions, no regular inspections are carried out, and registers are scarce for all bridges. The implementation of a BMS in Argentina grows slowly because of lack of resources for bridge rehabilitation. Nevertheless, there is a BMS developed by Argentinean Consulting Engineers that is especially applicable to bridge networks and conditions prevailing in developing countries.

The system, called SIGEP (Spanish for BMS: Sistema de Gestión de Puentes) by the authors, was implemented under different local names in Guatemala, El Salvador, and Bolivia, and also in a privatized highway network for the accesses to Buenos Aires in Argentina. In its first presentation SIGEP was awarded the prize Ing. Luis De Carli by the Transit and Road Engineering Argentinean Congress in 1998. The implementation of SIGEP in Guatemala was awarded by the International Road Federation (IRF) in the Australia meeting of 2002. SIGEP implements an algorithm based on so-called fuzzy logic, considering the uncertainty per se of evaluations, the great amount of variables determining the condition state and vulnerability of a bridge, and the broader variables, which are usually not measurable.

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