CASE STUDY

RM Bridge Streamlines Design and Analysis of South America's Longest Suspension Bridge

Chile's Ministry of Public Works Uses Bentley Software to Unite the Island of Chiloe with Mainland Chile

Project Summary

Organization:
Ministerio Obras Públicas de Chile

Solution:
Bridges

Location:
Island of Chiloe, Llanquihue, Chile

Project Objective:
- Design and deliver the USD 740 million Chacao Channel Bridge to connect the Island of Chiloe to the mainland.
- Perform bridge analysis and construction simulation to determine structural resiliency during seismic and natural events.

Products used:
RM Bridge, gINT

Fast Facts

- The Chacao Channel Bridge will be the longest suspension bridge in South America, with 1,055- and 1,155-meter main spans that will clear the Chacao Channel by 50 meters.
- Bentley software streamlined the evaluation of alternatives that were prepared under changing design requirements, and facilitated work sharing and cross checking among team members.

ROI

- Global analysis with RM Bridge saved time and reduced costs by simplifying information exchange with other software.
- The detailed wind studies, time-history analyses, and seismic scenarios helped to improve the quality of the bridge design.
- Upon completion in 2020, the Chacao Channel Bridge will improve quality of life, commerce, and tourism for the Island of Chiloe and the port city of Puerto Montt.
- Replacing the sporadic ferry service across the rough channel is estimated to result in a 6 percent return on investment for the Chilean government.

Suspending Disbelief

In southern Chile off the coast of Llanquihue Province, the people of Chiloe have cultivated an island culture steeped in history and tradition. This isolated enclave is famous for its coastal towns with colorful houses built on stilts, 17th century churches designated as UNESCO World Heritage sites, and national parks teaming marine life. Yet to travel to and from the island, locals and visitors alike must book passage on an unreliable ferry for a 45-minute ride across the treacherous Chacao Channel.

Chile's Ministry of Public Works (MOP) first conceptualized a bridge to connect the Island of Chiloe to the port city of Puerto Montt on the mainland in the 1990s. After several false starts, a USD 740 million design-build contract was awarded in February 2014. Upon completion in 2020, the Chacao Channel Bridge will be the longest suspension bridge in South America at 2.75 kilometers. The asymmetrical structure will feature 1,055- and 1,155-meter main spans and three towers that rise to heights of 157, 175, and 199 meters. The four-lane carriageway on deck will soar 50 meters above the turbulent channel waters.

As the cabinet-level office in charge of all aspects of public infrastructure in Chile, MOP is overseeing the international consortium retained to take on the engineering and construction challenges presented by the highly seismic region, strong currents, deep channel, and high winds. The consortium, Consorcio Puente Chacao, is comprised of Hyundai (South Korea), OAS (Brazil), Aas-Jakobsen (Norway), and Systra (France). MOP's Department of Roads, which is in charge of Chile's road network, is responsible for design verification, structural evaluation, and bridge constructability. Local consultants are providing an independent design check.

Overcoming Site Restraints

Funded by the government of Chile as a public works concession (PPP), Chacao Channel Bridge includes three different public works projects: the suspension bridge, the access roads, and a service area. The aggressive 84-month schedule demanded rapid evaluation of design alternatives, streamlined design studies, highly collaborative workflows, and accelerated reviews. MOP implemented Bentley's RM Bridge to save time and reduce costs. The application is used to perform bridge design, analysis, and construction simulation to determine resiliency during seismic and natural events. It streamlines the massive analytical tasks and automates complex design and engineering functions.

When work began in 2014, the project team confronted several extreme challenges in designing the multi-span suspension bridge across Chacao Channel. The project site is in a remote area of the Los Lagos region, 1,100 kilometers south of Santiago. The channel separates the 200-kilometer-long island from the mainland, but both land masses are part of the coastal range noted for high seismicity. The bridge is just 80 kilometers from the fault zone where a disastrous 9.5 magnitude earthquake struck Valdivia, Chile, in 1960. In 2010, an earthquake of 8.8 magnitude struck offshore of Concepción, about 650 kilometers north. Seismicity was the most challenging design criteria for the team.

Additionally, the channel is prone to critical winds of up to 208 kilometers per hour, and ocean currents reach 9.7 knots or 18 kilometers per hour, with 8-meter waves. The deep channel plunges 120 meters to the sea floor. Mid-channel, rock protrudes enough to provide a base for the central support tower, but it presented problems with subsidence.

The bridge design features 1,055- and 1,155-meter main spans that will clear the Chacao Channel by 50 meters.

"RM Bridge has been a very powerful tool for the challenging design tasks of the Chacao Bridge, improving the checking process and ensuring quality in the process. The software is an excellent platform for innovation."

— Ing. Matias Valenzuela, Ph.D. Ministerio Obras Públicas de Chile

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Fast, Accurate Analyses

To ensure the safety and serviceability of the bridge under these conditions, and adhere to strict environmental qualifications that protect local flora and fauna, archeological zones, and aboriginal communities, the project team performed global analysis and time-history analysis with RM Bridge based on multiple engineering studies. The analyses investigated factors influencing linear, non-linear, static, and dynamic behaviors, including bathymetric, geodesic, geologic, geotechnical, seismic, topographic, and aerodynamic. MOP implemented gINT to streamline data management and reporting for the geotechnical and geoenvironmental work.

Wind tunnel analysis studied the bridge's aerodynamic stability both in parts (deck, towers, suspension cables) and as a whole. MOP used the advanced wind analysis capabilities of RM Bridge to conduct computational fluid dynamics studies. The seismic analysis focused on specific response criteria for both bedrock and soil behavior. The effects of wave impacts in the event of a tsunami also had to be considered. This comprehensive probabilistic seismic hazard analysis (PSHA) defined the structural response to seismic activity.

The structural design of Chacao Channel Bridge was guided by seismic design criteria according to AASHTO LRFD Bridge Design Specifications (2012), in conjunction with Chilean Standards (NCh), Japanese normatives, and Eurocodes. Given the harsh environmental conditions, RM Bridge's parametric analysis capabilities reduced the time required to evaluate alternatives and verify the structural design. RM Bridge proved to be a powerful tool for checking complex structural designs and reacting quickly to conditions in the field that require design modifications.

"RM Bridge has been a very powerful tool for the challenging design tasks of the Chacao Bridge, improving the checking process and ensuring quality in the process," said Matias Valenzuela, Ph.D., Ministerio Obras Públicas de Chile. "The software is an excellent platform for innovation."

Economic Bridge Design

RM Bridge helped to resolve issues that arose during construction due to the harsh conditions. Because the bridge is asymmetrical, with two spans of different lengths, the three pylons carry the burden of balancing the uneven loads. The central, 175-meter tower, shaped like an inverted-Y, became the focus of intense mitigation efforts when subsidence of the mid-channel rock formation created a construction challenge. The problem was solved by using the advanced dynamics and wind analysis capabilities of RM Bridge. Performing 3D computational analysis aided in evaluating alternatives and improving the design of the central tower.

When construction is complete, MOP will assume responsibility for operations and maintenance of the bridge. MOP instructed the project team to consider operations and maintenance efficiency and economy in the bridge design, so the Ministry anticipates that the lifecycle costs of this infrastructure asset will be optimized. Overall, MOP credits the high-quality design for this multi-span suspension bridge to the team's using the most advanced bridge engineering applications available.

With a 100-year design life, the Chacao Channel Bridge will improve quality of life, commerce, and tourism for the Island of Chiloe and the port city of Puerto Montt. The bridge will replace the sporadic ferry service across the rough channel and shorten the trip to minutes. Improved access and mobility between the mainland and the island will encourage an influx of professionals to live and work in the area. The bridge will also serve as a conduit for water, power, and telecommunication lines, creating the opportunity for new development. Ultimately, Chacao Channel Bridge will connect the Island of Chiloe to Chile's highway system, uniting the island community with the rest of the country. The Chilean government estimates the advent of improved commerce will result in a 6 percent social return on investment in the region.

The Chacao Channel Bridge is an emblematic project, as the first long-span suspension bridge in Chile. It represents an opportunity for the exchange of technological know-how among MOP and the partners participating in the consortium, and demonstrates that Chile provides a favorable business climate for developing large-scale projects.

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