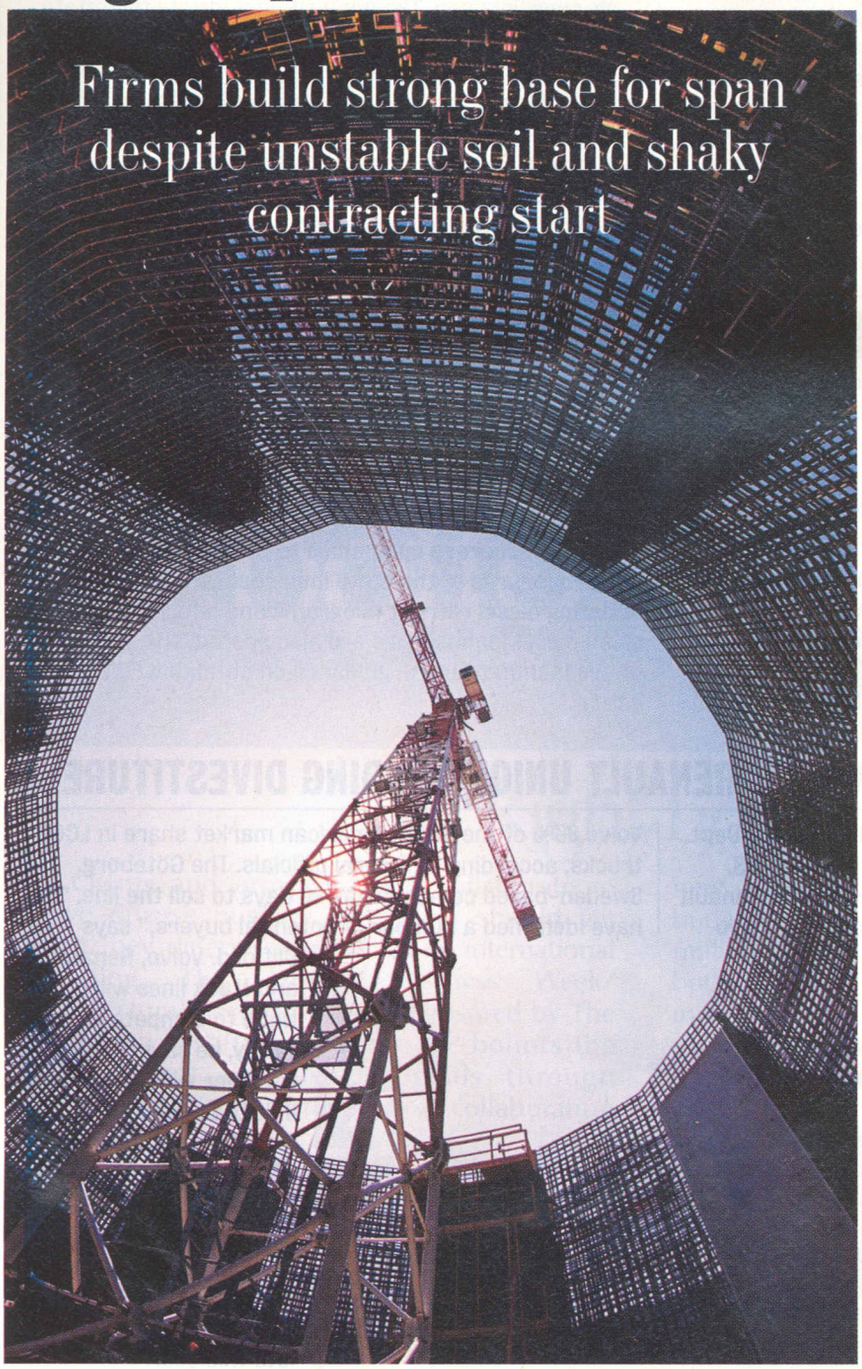
Bridge Builders Tackle Olympian Challenges

Firms build strong base for span despite unstable soil and shaky contracting start



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DEEP INSIDE Mammoth piers mark end of a 15-year struggle to get work started.

A concrete bridge footing big enough to hold almost two football fields now floats in Greece's deep Gulf of Corinth, after 15 years of hard bargaining and tough engineering. The $650-million Rion-Antirion project to bridge the seismically active body of water with five cable-stayed spans is at full pace, but the only evidence of a finished structure gets smaller every day.

"People from outside never see progress," says Philippe Tavernier, a senior site manager with the Gefyra Joint Venture (GJV), part of a build-operate-transfer team. With the 90-m-dia pier base slowly descending into more than 60 m of water, only construction of the tapering shaft is visible. Passing ferry riders "will see less and less as time goes on since the concrete diameter decreases," he says.

In the next two years, four concrete piers will emerge from water where a 16th-Century Christian fleet attacked the Ottoman navy at the Battle of Lepanto. Remnants of Turkish forts overlook a giant barge laying smooth gravel beds for the pier bases and reinforcing soil against seismic slip circle failures with hundreds of 2-m-dia tubes. A cone of shuttering just above water marks the first pier in construction. With so much under water, deck erection is not scheduled to start until late 2002.

Athens-based Gefyra S.A., the BOT concession owned by six Greek contractors and France's Groupe GTM, has battled for 35 years to build and operate the 2.9-kilometer-long bridge. The structure includes a 2.25-km cable-stayed section with three 560-m main spans, under a $510-million fixed price, lump-sum design-build contract.

START. Jean-Paul Teyssandier, now Gefyra's managing director, came across the project in 1986, while discussing potential work for GTM, where he ran major projects. The Greeks wanted a fixed link to eliminate the existing ferry on the main route northwest from Athens. GTM, which is now merging with another Paris-based contractor, Vinci S.A., did a proposal resembling what is now being built.

A year later, the government solicited bids for a publicly financed design-build contract. London design firm Rendel, Palmer & Trit-

AFLOAT Piers cast in dock are towed to prepared seabeds and ballasted down.

ton (now Highpoint Rendel) outlined a reference scheme of a long-span suspension bridge on piled foundations. The U.K. firm and Eupalinos Consultants SA, a local engineer, served as adviser on the bidding.

GTM offered the four-pylon option on shallow pad foundations. With no bedrock within reach, the French discarded friction piles. Of the other two bidders, a Greek consortium stuck to the reference scheme, while a German group submitted the most ambitious plan—doubling the world length record at the time for cable-stayed spans at more than 1 km. "We felt that it was a step too far," recalls Joe Barr, now Highpoint Rendel technical director.

A new government elected in the late 1980s dropped design-build bidding in favor of build-operate-transfer. With the ministry undertaking more soil investigations, the second bid improved technically. But the ministry's inexperience in privately financed procurement created a minefield.

Teyssandier contrasts Rion-Antirion with a BOT contract for the U.K.'s cable-stayed Severn bridge, won by a GTM joint venture. That project had gone smoothly, but the British benefited from the earlier Dartford crossing of the River Thames. On the Rion-Antirion project, "a major difficulty was the lack of any kind of precedent in structuring a private-public financing in Greece," says Neil Alexander, one of Gefyra's former financial advisers with Bank of America in London. Contracts had been drafted "without the necessary attention to the financing aspects."

Hours spent attempting to improve the draft contract's bankability largely failed, says Teyssandier. Hoping for better terms later, Gefyra bid anyway. Six consortiums prequalified, but a new left-of-center government more hostile to privatization won power in 1993. It reviewed the contract, but decided to proceed, receiving bids in December.

BATTLES. Delivering its bid in numerous boxes, Gefyra was surprised to find only one rival, who submitted a slim document outlining plans for a sunken tube tunnel. With all the prequalified bidders pulling out, "I was quite worried, I can tell you," says Teyssandier. "Most people were thinking it was just a dream and would never proceed."

A review of the surviving bid by five committees took up most of 1994. Late that year, the contract was threatened by a complaint to the European Commission, alleging that Gefyra's offer had not complied with rules requiring firm financing. Confident with its technical proposal, Gefyra had quoted a fixed-price lump sum for the construction. But because the company was unhappy with many conditions of the proposed agreement, its commercial offer—including financing—was conditional on an acceptable deal being reached.

The EC cleared the contract the following spring, allowing Gefyra to finally negotiate a concession agreement that would attract banking support. "It was the beginning of a long process," says Teyssandier. He remembers spending up to nine hours a day in hotel rooms redrafting the contract over six weeks between June and July 1995.

Having secured a viable contract, Gefyra

RISING Stabilizing steel tubes are driven into cellular pier bases cast in drydock.

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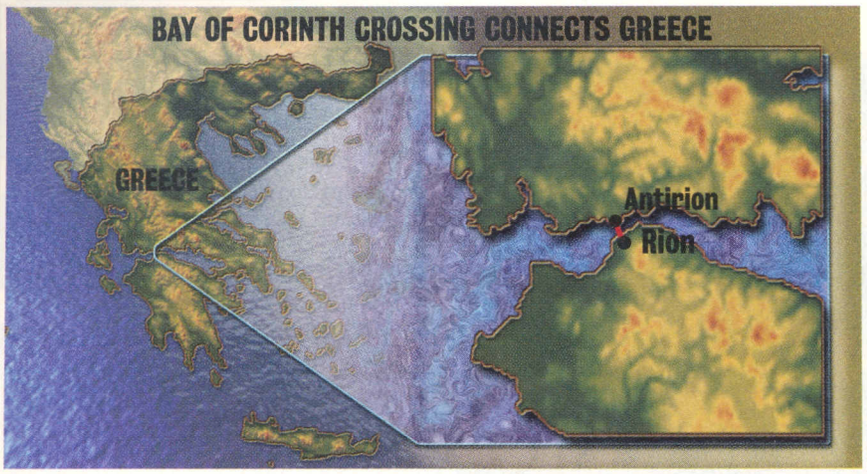


then discovered that the European Investment Bank (EIB) was uninterested in providing necessary loans. Long-term financing was vital, says Alexander. "Construction...was expected to take up to seven years, which ...was at the long end of the commercial banks' appetite for Greek risk," he says.

As an institution of the European Union, the bank must test the broad benefits of its loans. By Gefyra's reckoning, the crossing itself was commercially viable with tolls, but with macroeconomic issues included, it was "just adequate," says Anthony Goltsos, the bank's account officer. With pressure from the consortium and government, however, EIB's attitude softened "little by little" and it finally agreed in December 1996 to finance the loan. "The bank decided to go ahead, not on the basis of an improved economic profile...[but]of long discussions on the financial engineering," says Goltsos.

Gefyra secured $320 million in long-term EIB loans, plus $270 million from the government. The shareholders contributed $60 million in equity. EIB does not accept construction risk, so Gefyra got international banks to guarantee its loan until the end of work. The issue of security against defaults caused by the government or during the operational phase led to more months of talks, with meetings attended by up to 25 lawyers, says Teyssandier. "The concessionaire was paying for all of them except the lawyers of the state," he says. With a series of standby loans from the banks and governments involved, EIB felt sufficiently covered to sign the deal, says Goltsos.

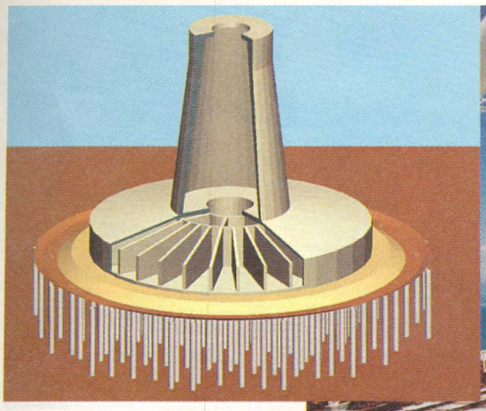
REDESIGNS. Resolving financial details that year kept Teyssandier in London with bankers one-third of the time. His Paris-based colleague, Guy de Maublanc, used the time to refine the engineering.

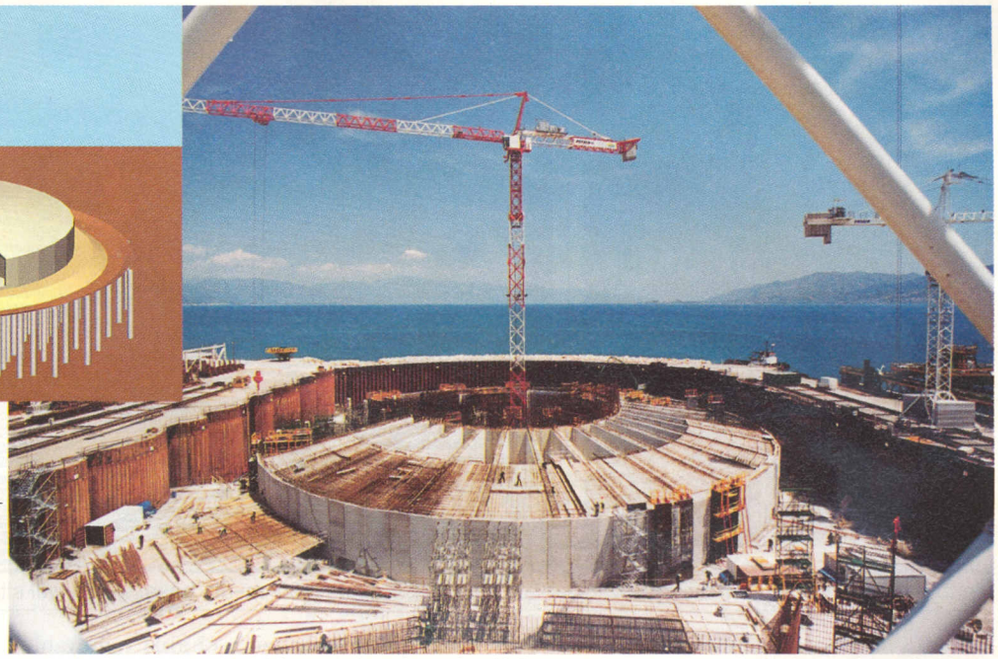
De Maublanc had returned to Paris in 1996 from running the BOT contract for the Prince Edward Island bridge in Canada. He was an old hand at big bridge BOT contracts, having previously held a similar post on the Severn crossing joint venture. Back in Paris, "we had time to start thinking about the design and making improvements," De Maublanc says.

Originally, the bridge's soil-reinforcing tubes were to project into a 0.5-m-deep void under each pier base, formed by a steel skirt and later to be grouted. Atop the piers, huge seismic isolation devices were planned to reduce pylon vibrations. But with input from the bank's technical adviser, New York City-based Steinman Boynton Gronquist & Birdsall, and the independent checker, Vancouver-based Buckland & Taylor Ltd., these and other features of the design changed during the engineering review in Paris.

PHOTO COURTESY OF GEYFRA, MAP BY NANCY SOULLIARD FOR ENR

VETERAN BARGE Barge was modified from previous work on U.K.'s Severn bridge to dredge gulf for Rion-Antirion crossing.





CASTING Huge pier bases are cast in a 230 x 100-m dry dock, then towed to site.

If the tops had been grouted to the pier bases as originally planned, soil reinforcing tubes would have acted like a lever during earthquakes, loosening the ground, says George Leventis, a principal of Langan Engineering and Environmental Services P.C., Steinman's New York City-based foundations subconsultant. Grout could also crack and the nature of the whole connection could be different at the next tremor.

Improving seabed detail "was probably the most difficult design item in the project," adds Peter Taylor, a Buckland & Taylor principal. After sophisticated analysis and centrifuge testing, GJV designed the base to slide on a gravel bed covering the tube tops. Improving the foundations' vibration damping allowed elimination of pylon isolation devices, which were not available in the required sizes.

The plan also was to build a composite deck integral with the pylons in four sections, linked by drop-in beams at midspans. But the designers ultimately decided to scrap the drop-in beams for fear of large movements during erection. They chose to support the deck entirely by cables and build it in one piece, with movement joints only at the ends. Sideways hydraulic dampers will steady it against the pylons in the event of earthquakes.

In the final design, the bridge will rise from four 90-m-dia seabed cellular concrete bases. Under each of three bases, more than 150 steel tubes, each 2 m in diameter, will be driven 25 m into the seabed to reinforce the soil. That step is not needed under the fourth base. Each base has a 9-m-high perimeter wall topped by a slab, sloping gently up to the 38-m-dia conical pier stem.

For the deepest pier, the cone rises more than 63 m over the bed to project 3 m above water level. From there, a 24-m-wide vertical section rises nearly 29 m to the 15.8-m-high pierhead, which spreads to form the 40.5-m square base of the pylon's four legs. The legs converge over the next 87.6 m, merging into one vertical section for the final 25.4 m.

BASES. GJV is casting two cellular pier bases at a time near Antirion in a 230 x 100-m dry dock. The dock's two levels provide 12 m of water for casting the leading pier and 8 m for the one behind. The base and the leading 3.2-m lift of the tapering leg is cast in the dock before the nearly 17-m-tall structure is towed a few hundred meters to deep water.

GJV extracted the piled dock gate last summer for the first tow-out, floating the less advanced second pier forward into the deeper dock and sinking it by flooding. Temporary steel walls around the base top slab and sheet piles projecting from its sides seal the dock mouth, allowing it to be dewatered.

FLOORED A geotextile cover failed to protect the dock floor from concrete.

As work resumes in the dock, another team continues to cast the leading pier leg in deep water. Cells in the base are progressively flooded to sink the structure and maintain a constant working height above water. When the pier is tall enough to stand a few meters above water, tugs will take it to its prepared bed to be ballasted down. It will take up to 28 months to cast each of the remaining pier sections and pylons.

"The concept seems simple, but we discovered many tricky things," says de Maublanc. For example, when the first bases floated, lean concrete covering the dock floor was found clinging to nearly half of the undersides. The floor's geotextile cover had failed to form an adequate barrier. A more reliable impervious covering would not have provided enough friction to use the leading base as dock gate.

The contractor lost nine weeks having to chisel the concrete out from under the bases. With ample room under the leading pier, the contractor used a remote-controlled submarine excavator to remove the concrete. For the dock base, divers with handtools did the job. GJV rebuilt the dock floor with gravel, covering the upper level with impervious lining since it needs no frictional resistance. No covering was need for the lower floor, since only the first base would be cast there.

Gefyra lost more time when 1.5-m-dia tubes projecting 60 m from the seabed to anchor a floating bridge snapped from fatigue last year. Water movement had bro-

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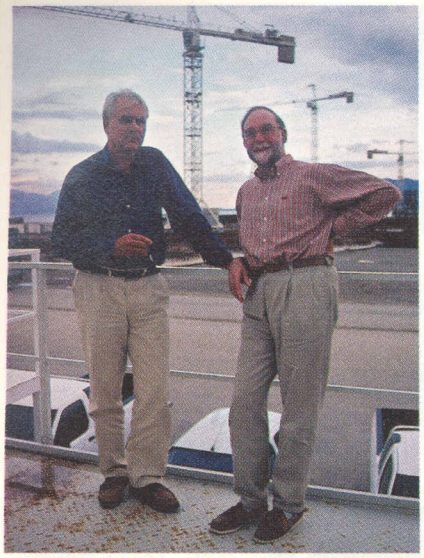


DETERMINED Teyssandier (right) and de Maublanc fought hard for bridge.

BASE WALK Rebar lines a 90-m-dia base, which will slide on gravel for damping.

ken welds made to extend the cantilevered tubes as they were driven into the bed. "We made a mistake in the design," concedes de Maublanc.

Similar welds had been used for six bigger tubes that were to steady the pier being cast in the gulf, but that plan was abandoned. GJV cut down the tubes and is anchoring the pier with chains instead.

BARGE. GJV began foundation work in October 1999, dredging bed locations. It is now working on the first dredged area with a 40 x 60-m jack-up barge, modified since its days on the U.K.'s Severn bridge. The bed is too soft to support the four barge legs, so the contractor replaced them with adjustable chains, anchored with concrete and tensioned to 400 tonnes. A second barge, equipped with dynamic positioning, maneuvers the first one and transports heavy items.

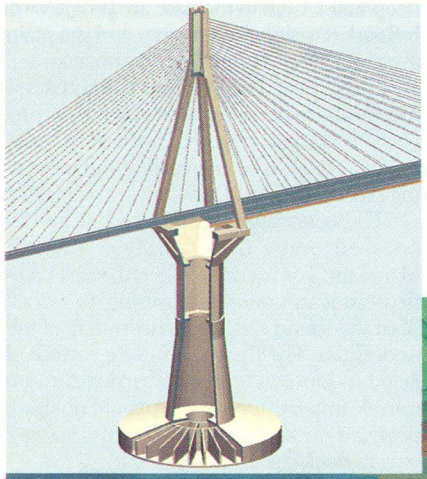
Equipment for driving soil reinforcing tubes and preparing the seabed is mounted on pontoons anchored to one end of the first barge with steel arms. A movable 2-m-dia steel tube, reaching nearly to the sea floor, guides piling equipment and deposits sand and gravel on the pre-dredged bed. Sonar scans of the finished gravel show it is within the 5-cm tolerance, says Marc Augier, the barge manager.

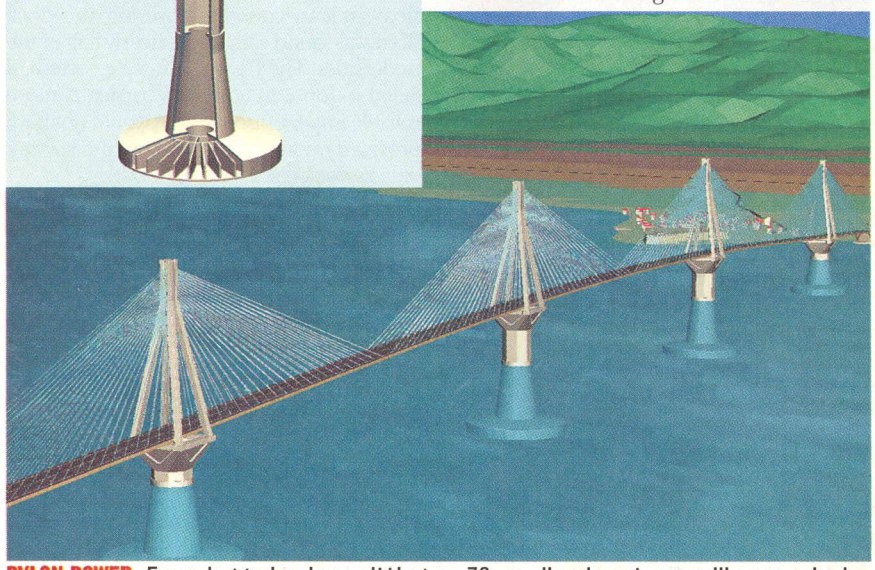
Last July, GJV began its first base by laying a 90-centimeter sand layer followed by piling, leaving tubes projecting 1.5 m from the bed. Rounded river gravel came next to cover the tubes by about 40 cm, followed by 50 cm of crushed gravel. Moving the tube to some 40 positions, it will take about five months to complete each pier base, says de Maublanc.

FUTURE. Despite the snags, GJV is still eyeing a bonus by finishing work before a Dec. 24, 2004, deadline. Delays beyond then would mean heavy penalties. De Maublanc anticipates a 2002 start of balanced deck erection from each pylon, using a GTM-owned stay system. Bids for a 17,000-tonne steelwork fabrication and erection contract were received a few months ago, and de Maublanc plans to make an award in April.

Site work now appears to be running smoothly, rewarding the tenacity of the bidders for not balking at a technically challenging bridge with untested private finance procurement. The "quality of the sponsors" had helped reassure Alexander. And Teyssandier was determined to build the bridge. "I felt the Greeks wanted the project very much," he says. "What they didn't know was how to proceed." ❑

By Peter M. Reina in Rion





PYLON POWER Four-legged pylons sitting on 38-m-dia pier stems will carry deck.

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