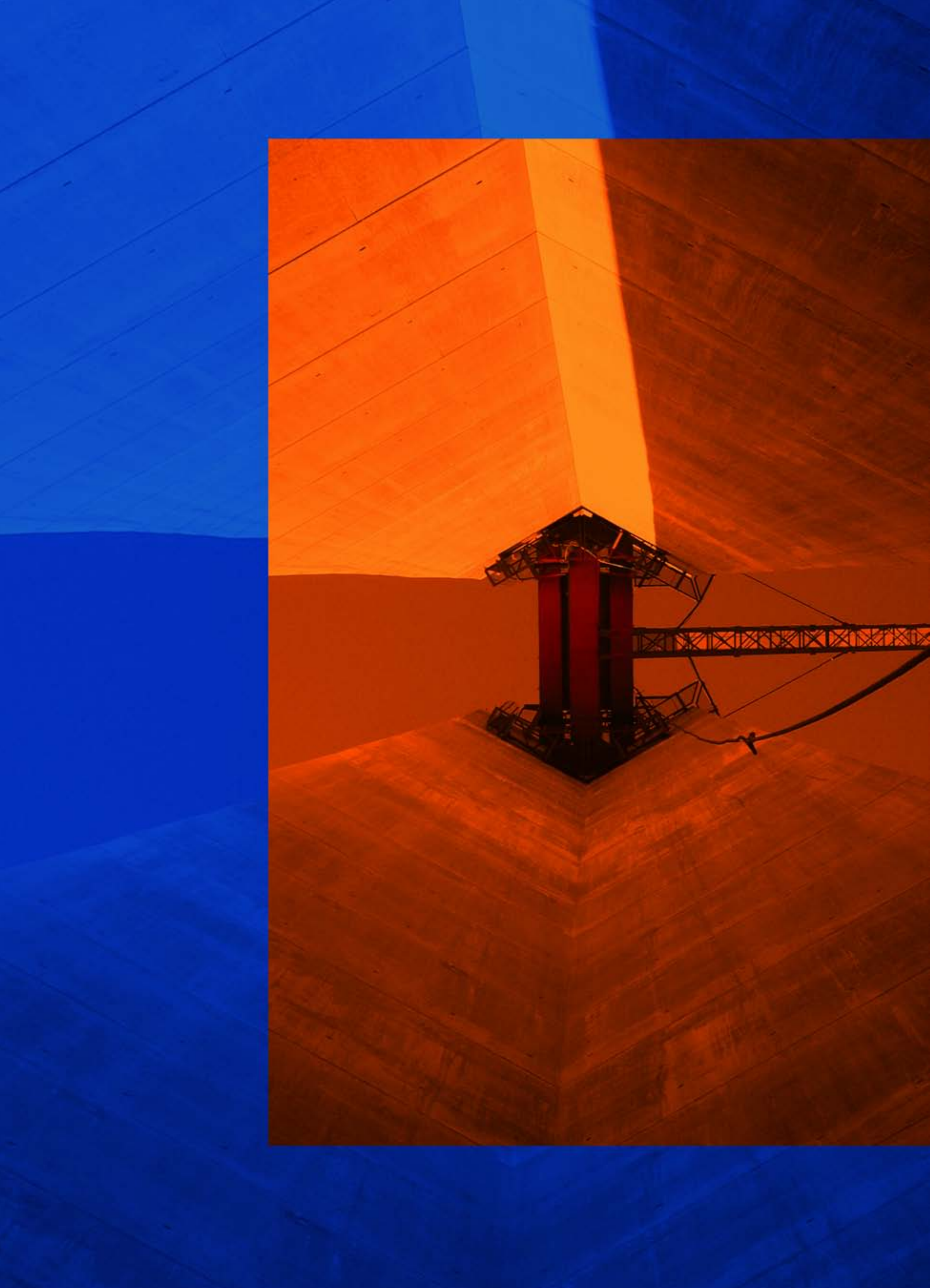


Millau Viaduct

By Marc Legrand

More than 20 years ago, the French Government approved construction of a new motorway from Clermont-Ferrand to Béziers. The A75, measuring 350 kilometers, would improve access to the remote Massif Central region. And since Paris was already linked to Clermont-Ferrand via the A10 and A71 motorways, the new road would provide a valuable alternative to the often congested Rhône Valley route linking Paris and northwest Europe to the Mediterranean coastline and Spain.

Under the roadway planning policy of the time, the motorway was to be built by the state and therefore toll-free. Government bodies studied possible routes and addressed inquiries to local authorities and populations. Once the final route was chosen, the biggest technical obstacle would be crossing the River Tarn in the vicinity of Millau, where the Tarn Valley forms a breach about 300 meters deep. At the recommendation of Michel Virlogeux, a government engineer and designer, the head of the Roadways Department determined in 1991 that the valley should be crossed directly by means of a large viaduct connecting the plateaus to the north and south of the River Tarn.

The Millau Viaduct is 2,460 meters long and stands on seven piers and two abutments, making a total of eight spans: two end spans of 204 meters and six central spans of 342 meters.

Following an examination of various viaduct proposals, a Roadways Department panel selected a project for submission to the French Public Works Ministry. In July 1996, the Ministry decided in favor of a multi-stay viaduct project masterminded by Michel Virlogeux and engineered by Lord Norman Foster and the Thales, Arcadis et Serf design offices.

With design work still in progress, government offices began to investigate financing solutions for the A75 project, estimated at around 2 billion. Given the proposed construction, however, the issue of public funding proved problematic, as a viaduct project cannot be broken down into phases, unlike an ordinary section of motorway. An order would therefore have to be placed for the viaduct as a whole.

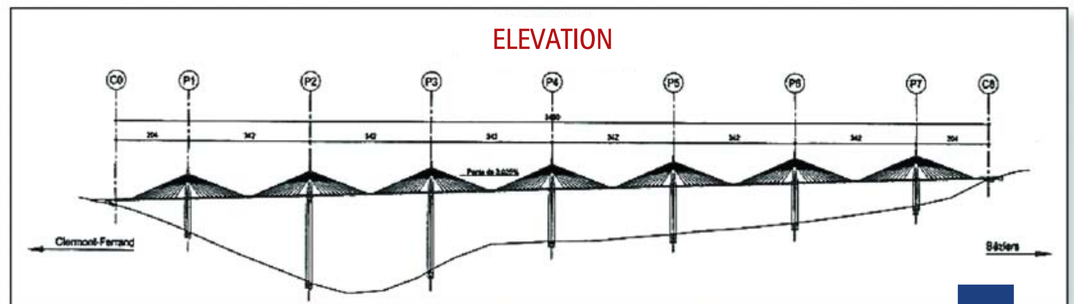
To expedite completion of the A75 link within state budgetary limits, the French government in 1998 decided to call in a private investor to handle construction of the Millau Viaduct. Under this arrangement, the viaduct was to become a discrete venture, entirely separate from the state-funded A75 motorway project. The private concession-holder would complete the studies in progress, proceed with construction, and handle maintenance and operation. Since there would be no public subsidy or guarantee, remuneration would be on a toll basis.

A tender procedure was launched to select a concession holder for the project. The four short-listed groups were provided full project documentation in January 2000 and asked to submit bids by 21 November 2000. In February 2001, a commission chaired by a senior ministry official came down in favour of the bid placed by Eiffage construction group.

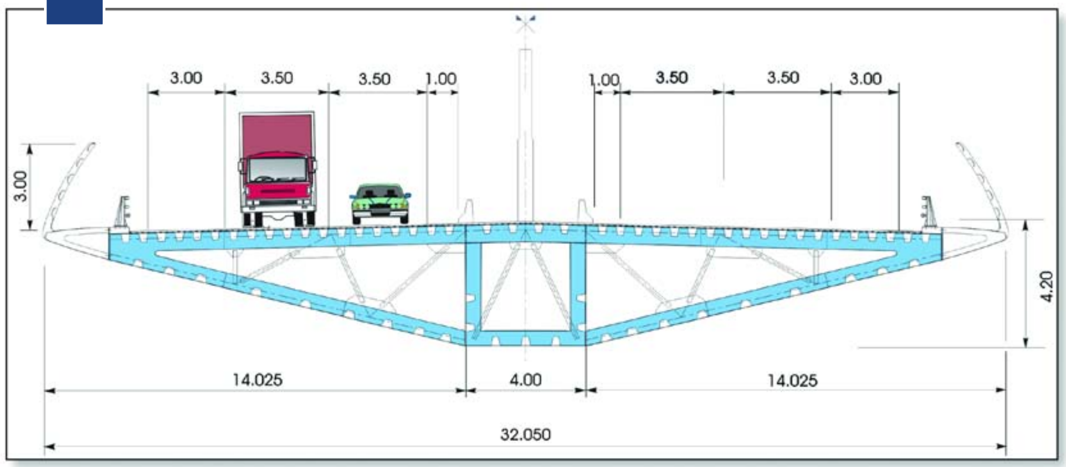
Following contract negotiations, Eiffage was officially appointed concession holder for the Millau Viaduct in October 2001. The contract stipulated that the viaduct should open by 10 January 2005 and that the concession would run until 31 December 2079.

Project

The Millau Viaduct is 2,460 meters long and stands on seven piers and two abutments, making a total of eight spans: two end spans of 204 meters and six central spans of 342 meters. The shortest pier is 77 meters high and the tallest 245 meters - the highest in the world.



Each reinforced concrete pier stands on a rectangular reinforced concrete footing 3 to 5 meters thick. Each footing has four reinforced concrete foundations, 5 meters in diameter and 10 meters deep. Each pier is topped by an 87-meter mast from which the bridge deck is suspended by means of eleven pairs of stays.



Cross section of bridge deck

The bridge deck supports a dual-carriageway motorway with 3-meter hard shoulders and a 4.45-meter central reservation where the masts stand and the stays are anchored. At the outer edges of the hard shoulders are rails calibrated for heavy-goods vehicles, plus 3-meter-high windbreakers made of disjointed blades of translucent polycarbonate, which reduce wind-sway effects while still affording spectacular views over the Tarn Valley. As seen in the cross-section drawing, the deck is trapezoid-shaped, 4.2 meters high, 32 meters wide at the top (the road surface) and 4 meters wide at the bottom. The deck is made of steel sections 12 to 14 meters long.

An asphaltic concrete surface course (specially designed by Eiffage) 7 centimeters thick sits on top of a sealing course, on top of the metal plates of the deck. The roadway has a longitudinal gradient of 3.025 percent from north to south and follows a slightly curved trajectory, with a radius of 20,000 meters. This arc enables the motorist to see all the masts and stays when entering the viaduct; a straight trajectory would have produced an unpleasant toboggan effect for motorists descending from the higher end of the viaduct at the south.

Key figures on materials used for building the viaduct:

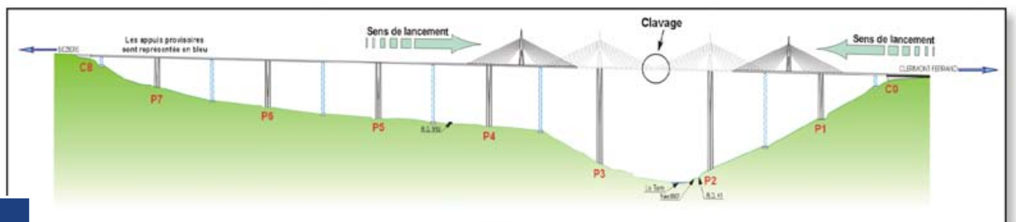
- Concrete 85,000 cubic meters
- Passive reinforcement 13,000 tons
- Metallic deck structure 36,000 tons
- Masts 4,600 tons
- Stays 1,500 tons
- Road surface 10,000 tons

Construction Methods

In its bid for the project, Eiffage realized that construction lead time would be a crucial selection criterion; the company thus opted for a construction method that would involve gradually pushing out each successive steel deck section until it reached the next supporting pillar. This process was conducted at each end of the structure. In order to halve the span distance from 342 meters to 171, temporary support columns were erected between the actual viaduct piers. These intermediate pillars took the form of 12-meter square pylons in metal tubing, the tallest measuring 172 meters and weighing 1,200 tons.

The deck was made up of 2,078 steel plates measuring about 4 by 20 meters, prefabricated at the Eiffage plant in Lauterbourg, then carried to platforms at the northern and southern ends of the bridge for assembly into full deck sections.

Once a deck length of about 300 meters had been assembled, it was pushed out by hydraulic pistons to overhang the edge until it reached the first pier. The next section of 171 meters was then welded up, and the whole assembly pushed further out to reach the first intermediate column. Then the next 171 meters was welded up and pushed out to reach the second pier, and so on. A total deck length of 1,743 meters was pushed out from the southern end, and a length of 717 meters from the northern end, with the two lengths meeting above the River Tarn, ready for welding together.



Assembly Method

This method brought several advantages:

- Deck manufacture at the Eiffage plant and deck assembly on-site could proceed simultaneously with pier construction.

- Quality and safety risks were considerably reduced by having the bulk of the deck assembly work performed at either the plant or the bridge-end assembly platforms, rather than over the deep valley.

- The launch phases, during which each successive deck section was pushed out to overhang the edge, were relatively short. With the deck moving at an average speed of 4 meters per hour, it took about two days to cover a 171-meter span. The bulk of the cycle time was taken up by section assembly, with each 171-meter section taking around four weeks to assemble. With very strong winds in this part of France, section assembly over the void might have proved hazardous. The gradual overhang method, however, meant that the only weather requirement would be low wind speed (below 85 km/h) during the two days each section was pushed out (i.e., every four weeks). The schedule would therefore suffer minimum interference from weather conditions.

- By performing a substantial proportion of construction at the plant rather than at the site, the project was more environmentally friendly. A conventional concrete bridge deck would have required 5,000 more truck round-trips, carrying cement, aggregates and reinforcing rods.

The steel masts were prefabricated at the plant, assembled at the bridge-end platforms, and transported one-by-one to their final locations on a multi-section trailer once the entire deck had been assembled, ready for tilting up to vertical using a special hydraulic system and welding onto the deck. Considerable time was saved by building up the masts simultaneously with the deck assembly.

Viaduct construction took just three years, with key dates as follows:

- December 14, 2001 — First stone laid; Earth-moving work started
- February 1, 2002 — Deck prefabrication started at Eiffage plant
- May 2, 2002 — Pier base construction started
- February 26, 2003 — First deck section pushed into place
- December 9, 2003 — Pier construction completed
- May 28, 2004 — Last deck sections linked up over River Tarn
- August 10, 2004 — Masts erected
- September 15, 2004 — Stays tensioned and roadway surfaced
- December 14, 2004 — Viaduct opened by French President

Finance, Revenues and Operation

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Eiffage's chairman decided that the company would finance the project from equity. This would involve an average investment of 130 million per year over three years – well within the company's capabilities, given a gross cashflow capacity approaching 300 million. Construction risks would therefore be borne by the company best able to appreciate them, and finance cost would be optimized to produce well-adjusted toll pricing consistent with the project outlay. In addition, IEB (European Investment Bank) accommodated funds for the project on account of its virtues as a European infrastructure.

Naturally, Eiffage might later wish to use its financial capacities for other purposes, and therefore seek bank finance. But by then, construction risks will no longer be an issue, and hypotheses on concession profitability will have been validated by data on actual income. This means risk conditions attendant to a subsequent loan would be much lower, and the finance cost accordingly much lower than if a loan had been sought at the onset of the project.

Tolls have been set on the basis of traffic studies to maximize use of the viaduct under the constraint that the concession should attain profitability of around 15 percent on invested capital without income from public subsidies.

The utility of the new viaduct grows substantially during July and August, when summer holiday traffic would previously cause notoriously high congestion levels at Millau, with four-hour jams being commonplace. This seasonal variation is reflected in the toll pricing for cars, set at 6.50 in July and August, as opposed to 4.90 the rest of the year. These prices are highly advantageous: the Massif Central route from Paris to Barcelona, via the A75, is 60 km shorter than the Rhône Valley route, and motorists save about 15 in tolls and at least 45 minutes in journey time (much more during peak traffic periods in the Rhône Valley). The toll for heavy-goods vehicles is 24.30.

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The tollgate at the northern end of the viaduct has 14 lanes with capacity for extension to 18. It accepts all payment methods useable on the rest of the French motorway network. The operations centre is located in the vicinity of the tollgate and is staffed round-the-clock by supervisors responsible for monitoring viaduct user safety by means of mast-mounted cameras covering the whole of the viaduct road surface. The cameras are coupled to automatic incident-detection software that will trigger an alarm to warn the supervisor of abnormal traffic conditions. In addition, there is always at least one patroller on duty, ready to implement emergency safety measures pending arrival of emergency services, police or breakdown trucks.

A special platform near the tollgate handles winter service functions with stocks of road clearance materials (salts, calcium, brine) and bays for special clearance machines (trucks, salt spreaders and snowplows). Preventive measures under winter conditions are determined on the basis of meteorological data from the viaduct's weather station and forecasts provided by the Météo France weather service.

In all, the Millau viaduct employs an operational workforce of around 50 persons.

However impressive the figures and technical data on the Millau Viaduct, the most important feature of this extraordinary bridge is undoubtedly the human commitment it mustered. The very short construction lead time of just three years owes its success to the extraordinary motivation of Eiffage personnel and support from the local population and local governments. All involved in the project - managers, engineers, technicians and production staff - were there on the bridge deck when the Millau Viaduct was officially opened by the French President, to share official recognition for the completion of this major roadway project, which involved more than two millions hours of work with no serious accident.

The new viaduct was officially opened by Jacques Chirac on December 14, 2004, and opened to traffic on December 16. Two weeks later, during the return from the Christmas holidays, it was crossed by 21,000 vehicles. For once, the town of Millau reported no traffic jams.

Marc Legrand is Executive Director of Compagnie Eiffage du Viaduc de Millau, a French construction group with a workforce of 45,000 and annual revenues exceeding 7 billion euros. He can be reached at mlegrand@construction.eiffage.fr