

# viaduc

ÉDITÉ PAR LA COMPAGNIE EIFFAGE DU VIADUC DE MILLAU

## The deck sets out to challenge the void

### What is the purpose of a leading beak?

With 171 metres between the piers and the temporary support towers, the cantilever of the deck will be considerable during the last metres of each launching phase. It was therefore decided to add a leading beak, a sort of metal framework, to the front edge of the deck. This will allow the deck to reach the supports more quickly and stabilise the structure, especially in the case of storms or violent winds.

On March 25 and 26, 4,200 tons of structure advance towards the first pier, passing over a temporary support tower.

### Nîmes, the shortest route

How to bring the different parts of the viaduct pylons from Alsace to Millau? In theory, the shortest route would be to go to Lyons, and then take the A75 motorway from Clermont-Ferrand. The problem is that the sections to be transported cannot pass under bridges that are 4.5m high! The trucks therefore have to take the road south and drive up from Montpellier. However, there is a snag there too! "We have to cross bridges limited to loads of 80 tons or to a clearance of 5m", explains Bernard Martin, commercial director of the Capelle transport company. "It's not enough, because that is precisely the height of the sections being transported".

The only solution: cross Nîmes and go up an avenue against the traffic. It is therefore impossible to drive by day because this would cause traffic jams in the town. The municipal technical services have organised for operations to take place at night, so as not to inconvenience normal traffic in the town. An awkward point: the passage under an arched SNCF national railway bridge. If, in the centre, the 6m clearance is amply sufficient, the drivers of the convoys have to steer accurately because it would be difficult to fit a sheet of paper between the sides!

**The first "launching" operation of the steel deck over the valley of the river Tarn was a success. More than 100 metres were bridged in two days. Between earth and sky, intense emotions were guaranteed.**

Slowly, the steel deck peeps over the void. Like a steel ship with a bright red leading beak 50m long, it advances slowly, with small 60cm steps. It takes an hour to cover seven metres. Where is it going? First, to reach the support prop Pi 7, a sort of gigantic temporary metal tower

32 metres from the south abutment, before continuing on its way towards pier P7, several tens of metres further away. This is just a first stage before a temporary pylon is raised and it continues its colossal "crawling" for almost two kilometres. Then will be the moment for its final rendezvous with the second part of the deck, advancing from the north abutment. The meeting is planned in a year's time, 273 metres above the river Tarn.

"This first "launching" of the deck over the void took place last March 25 and 26", points out Marc Buonomo, responsible for the Eiffel metal worksite. "It was a relief and a source of pride for the teams, since



everything went as planned... and in the sunshine ! During this operation, we advanced the 4,200 tons of the structure 114 metres and passed Pi7 by about sixty metres".

A few weeks earlier, the deck had been brought to the edge of the void, right at the end of the south abutment, during a first "pushing" operation on solid ground. This test under real conditions allowed all the

techniques and materials to be validated before taking the giant leap over the void. The operation was carried out in several stages using specifically designed mechanical parts, the transfer jacks. The deck is first raised just two centimetres by hydraulic jacks and then pushed forwards 60 centimetres before being lowered again. The jacks return to their initial position and a new cycle can then recommence.

## The support towers, temporary props

It is impossible to straddle two piers without an intermediary support. Halfway between each of the piers, support towers enable the deck to reach a temporary resting point. These are immense metal cages constructed by Eiffel, raised from ground level by a system of jacks and rack gearing that allow them to be lifted metre by metre so that a new 12m high section can be inserted. The racks are then brought back to ground level.

The tops of the support towers are equipped to carry the transfer jacks for the deck. The tallest of them (P1 2) will be 170m high and weigh 1,200 tons. They will all be dismantled at the end of the construction of the viaduct, after the cable stays have been placed under tension.



"In all, 64 transfer jacks placed on the abutments, the temporary towers and the piers will be used to push the deck", explains Jean-Pierre Gerner, director of works for Eiffel. "Their synchronisation is achieved by a central computer which allows the advance to be controlled to the millimetre". This is essential in order to avoid any scraping pressure on the piers, which would cause them to move horizontally.

Once this first advance had been completed, the "steel" teams began work again on the assembly of the deck: fitting the metal panels to the sides of the central box girder, fixing the upright elements in place to support the Plexiglas wind barriers, installing the electric sheathing and the tubes for water drainage... A maximum amount of equipment must be in place before each launching. It is a real puzzle, where each piece assembled is meticulously recorded and every weld can be authenticated. Once finished, a new stretch of almost completed motorway, 32m wide and 171m long, will be pushed out over the void. All that will then need to be done will be to complete the road surfacing and mark out the traffic lanes. ■

## Flashback

# A well prepared worksite

When the decree giving the green light for the construction of the viaduct was signed by the French government in October 2001, the objective was clear: start work as soon as possible. However, managing a construction site, which stretches over a number of kilometres with several hundred metres between its highest and lowest points and a river to cross, is not something that can be improvised.

Confronted with the need to create infrastructures to make it possible to drive between the different parts of the site, the French state took the initiative of carrying out a number of projects before work on the construction site actually started: a nine kilometre tarmac road linking the north and south abutments, a bridge over the river Tarn and a round-about at the entrance to the site allowing vehicles to circulate in complete safety, whatever the weather conditions. Moreover, the erection of a fence made the perimeter of the construction site secure, and a platform was planned to welcome visitors in comfort.

As a result, when Eiffage took possession of the site at the end of November 2001 (barely a month after the publication of the decree), the existence of this main track greatly contributed to making it possible for work to start on the earthworks and the foundations for the piers. "We laid out the secondary tracks giving access to the work platforms in the same spirit as the work which had already been done", underlines Jean-Pierre Martin. "Consequently, we have a construction site that can be used in all weathers". ■

## Interview

# Restoring balance to the road traffic crossing France

**When he visited on March 4 last, Patrick Gandil, director of roads at the French Ministry of Equipment, made a point of examining the construction site in its smallest details.**

**What are your personal impressions after this visit?**

The organisation and the means employed by Eiffage are really impressive. They should contribute to making sure that the ambitious objective to open the service to the public in 2005 is achieved. The professionalism of the teams and the quality of the work can be assessed from a number of details: cleanliness of the work platforms for assembling the formwork of the piers, which helps to give one a feeling of security even at 164 metres above the river Tarn, safety recommendations posted up everywhere on the site... From a technical point of view, the viaduct makes it necessary to develop innovative methods of construction. I have been able to admire the procedure for launching the deck, the complexity of the self-climbing formwork and, in a more roadway context, the thinking that has gone into the drainage system and the road surface which needs to be laid.

**What are the issues concerning this last link in the A75 motorway?**

When finished, it will on the one hand complete the A75 motorway between Clermont-Ferrand and Béziers and, on the other hand (via the A750 motorway) connect with Montpellier. It will service regions that until now have been far from the main transport infrastructures (south Puy-de-Dôme, west Haute-

Loire, Cantal, Lozère, Aveyron, etc.). By linking up with the rest of the national road network, it will also enable traffic flows to find a new equilibrium, particularly in summer, relieving congestion on some infrastructures which are close to saturation (Paris-Lyon, the Rhone valley and Languedoc corridors) and using the reserve capacity of the existing network (A71 motorway between Orleans and Clermont-Ferrand, the RN88 trunk road between Albi and Saint-Etienne...).

**With economic benefits as well?**

Of course! The Millau viaduct is going to be an important architectural and technical reference point. It will be a testimony to the expertise of civil engineering in our times, and will be famous for its height. Already quantities of visitors have already understood that, and are coming to see this exceptional construction site. In economic terms, the attraction of tourists will bring benefits to Millau and the surrounding area. Even today, the construction site is already generating an important amount of business locally; more than 500 employees are working on the site. Once the viaduct is put into service, its operation and maintenance will create permanent additional business, with recurring local benefits (professional taxes...).

## Profession

# Precise to the millimetre



Pierre Nottin, topographer

At the moment, it is very often easier to find Pierre Nottin at the top of a pier under construction, at a height of more than 100 metres, than in his office. Now that the fog has just surrendered its place to the spring sunshine, he is examining the formwork from every angle on pier P6 that is waiting to receive its penultimate pouring of concrete. "Being responsible for the topography of the construction site, one of my main tasks is to check that the formwork for the shafts of the piers is perfectly adjusted", he comments with conviction. "The actual positions of all the components must correspond exactly to their theoretical positions". This is an essential precondition to ensure that the

seven piers supporting the steel deck rise perfectly towards the sky.

## Satellites to the rescue

The use of GPS positioning as a system for measurement has revolutionised the way of working for Pierre and the two members of his team who are specialised in its use. It is reliable, precise, easy to use, lightweight and the speed with which measurements can be taken allow him to work in all confidence. Another advantage: bad weather conditions (fog...) do not prevent communication with satellites! "Just realise, it only takes about 20 seconds to take a satellite bearing" says Pierre enthusiastically. "Precision is maximal: five millimetres in planimetry and ten in altimetry. Just over a quarter of an hour is enough to take the fourteen measurements necessary to pinpoint the formwork of a pier shaft. Before GPS, these measurements would have taken at least an hour and a half!"

## On the look out for the slightest movement

If there is the slightest variance between theory and reality, Pierre insists that the formwork be repositioned. No concrete can be poured without his approval... nor without the green light from an independent surveyor who comes to validate the measurements taken. "It's sometimes a delicate situation to manage vis-à-vis the work teams on the site with whom you have to keep on very good terms so that everything takes place in the best of humour". Once back on the ground, Pierre goes off with another team to take the pulse of the viaduct piers from one of the twelve topographical towers placed across the construction site. These twelve beacons make it possible to measure how the construction is evolving – this time by traditional methods of geodesy. We take bearings from these towers on prisms set at every twenty metres in all the piers", Pierre explains. "Until now, no significant movement has been recorded". Another guarantee of the faultless stability of the highest bridge in the world. ■

Topographical beacon



Patrick Gandil, director of roads at the French Ministry of Equipment



# Concrete has a rendezvous with steel

Pier P2 (in the centre) has beaten the French height record.

The “concrete teams” on the viaduct are breaking records. After becoming the highest pier in France, other records are now in sight. Everybody however has only one objective in mind: finish the work in time to receive the steel deck. They are getting ready for a meeting.

The French record has been beaten! On February 21, pier P2 passed the height of the 141m Verrières viaduct (in the Aveyron region) which together with the Tulle viaduct had held the French trophy until then! It will only take a few more “lifts” of concrete before the 178m record set by the tallest pier in the world is wiped from the slate. This should be achieved during June.

Meanwhile, tirelessly, the cement trucks continue their circuit at the construction site: concrete is being poured on pier P4 and the concrete must not run short under any circumstances. Once filled, the 3m<sup>3</sup> containers (weighing about 7.5 tons) are lifted into the air by the cranes as though they were wisps of straw. It only takes a few seconds before they are placed on the top of the pier. “We are maintaining our cruising speed perfectly”, points out Jean-Pierre Martin, director of the construction project. “About 700 metres of combined height have already been achieved, representing two thirds of our objective”. This is a real performance bearing in mind the headaches of the winter season: snow and ice had brought work



to a standstill. In February, the cranes were placed in a weather vane mode for several days because of violent winds. In all, two weeks of forced inactivity, which now belong to the past. There are going to be clear skies ahead this summer for the civil engineering teams!

## A cap resting on two needles

Jean-Pierre Martin is confident, but nevertheless he does not underestimate the difficulties he will have to overcome. The pouring of the last metres of concrete is proving the most difficult challenge to meet. The piers at this height separate to form the eye of a needle. Space

is cramped on their tops, which appear to be inextricable tangles of hundreds of steel rods, pipes carrying the cables for prestressing the concrete, steel inserts etc... No less than five days (instead of the three normally required) are needed at this stage to prepare the lift.

Once the concrete work has been completed, two vital operations have still to be carried out: fixing the steel supports for the deck (four on each pier) and the positioning of a metal structure on the top of the piers. Monsters made of 120 tons of steel which have to cap the concrete. “It is a delicate operation”, reflects Jean-Pierre Martin. “These structures are intended to carry the transfer

jacks. They will have to withstand and transmit all the stresses while the deck is being positioned. The concrete-steel joints must therefore be achieved perfectly”.

A first pier, P7, has been finished, allowing the different stages of the construction of these concrete needles to be validated from A to Z. “We can now be certain that the piers will be ready in time, and that their construction will not delay the installation of the steel deck”, Jean-Pierre Martin assures us confidently. “It is now up to us to profit from the experience of P7 to analyse and optimise our work methods for the six other piers which are already well advanced”. ■

## A canopy made from a sheet of concrete paper

Even before the piers have been completely finished, the civil engineering teams are already thinking about the next step: the construction of the toll barrier to the north of the viaduct on the Causse rouge. An exceptional structure calls for an exceptional barrier! Its canopy will be constructed in Ceracem, very high performance concrete patented by Eiffage,

Welcome

## A brand new pavilion

Time has run out for the temporary structure, and it is time for the permanent. Opened to the public at the end of April, the “Viaduct Info Space” marks the completion of the facilities on the Cazalous welcome area. Financed by the Compagnie Eiffage du Viaduc de Millau and OTUA (Technical Office for Steel Use), this pavilion is a public welcome and multi-theme information centre representing 300m<sup>2</sup>. “Eleven information panels cover the different aspects of the viaduct design”, comments Frédérique Alary, responsible for the visitor welcome service. “A plasma screen shows the key operations which are features of the construction site - such as the erection of the temporary towers - and the work in progress. Not to forget an interactive scale model, 3m x 3m, of the viaduct itself”!

The departmental committee for tourism, the Millau tourist office and the Grands Causses regional natural park are also well represented. The reason is that in addition to the highest bridge in the world, it is definitely the whole of the Aveyron region that lovers of wide open spaces are invited to discover during their meandering along the lanes of the welcome pavilion.

The visit of the pavilion is a prelude to the panoramic views to be enjoyed over the entire construction site from the terrace. It is a visit not to be missed.

Free entrance - Open 7 days a week ■



Visitors to the “Viaduct Info Space” will be able to admire an interactive 3m x 3m scale model of the viaduct.



## Eiffage at a glance

All of the group’s subsidiaries are also mobilised on other important construction sites. In Portugal, they are starting work on creating the 155 kilometres of motorway linking the Spanish border to the town of Viseu. At the border between France and Switzerland, they are finishing the extension of the Basel-Mulhouse international airport. In the Paris suburb of Neuilly-sur-Seine, they are working on the 44,000m<sup>2</sup> Crystal-Park office complex for an Anglo-Saxon investor. ■

which makes it possible to construct both very thin and very slender shapes. The roof of the toll barrier will therefore resemble an enormous twisted sheet of paper, 98 metres long and 28 metres wide. With a maximum thickness of 80 centimetres in its centre, its alveolar structure will resemble the wing of an aircraft. It will be made of prefabricated sections, two metres wide, assembled together. In all, 1,000m<sup>3</sup> of Ceracem will be used, weighing a total of about 2,800 tons.

Partner

# Potain: five-star cranes

**High above the ground, seven men are keeping a lonely vigil. They are the operators of the gigantic Potain cranes which set the tempo on the construction site.**

As though standing on huge steel stilts attached to their individual piers, the seven cranes at the Millau viaduct turn in the sky to the rhythm set by the work. Made up of concrete tanks, metal frameworks, and formwork parts, they are designed to withstand all the demands made on them by the site and are essential for assembling this gigantic Meccano construction complex. "Each of them can lift a maximum load of 20 tons, which corresponds to the weight of the steel reinforcements put in place before each concrete lift" points out Daniel Barthélémy, commercial director at Potain.

The cranes at Millau are of the GME type since they are erected in sections, almost 6m long and 2.5m across. As the piers rise, additional sections are added – painted red and white to satisfy the requirements of civil aviation. The revolving turret is separated from the rest of the crane and lifted by a telescopic cage with hydraulic jacks. A new section is then inserted through an open side of the cage... and the turret secured in place again six metres higher.

### Making the work easier for the crane operators

Precise specifications were laid down for the cranes needed for the construction site. First, they had to be able to resist winds of up to 193 kilometres an hour \*, taking into account the difference in wind speed between the base and the top of the piers. By

calculating this differential, it was possible to determine exactly where to place the clamps, which attach the crane to the pier. It was moreover essential to make the work easier for the crane operators: lifts for the operators, air-conditioned cabins, space to rest with a corner for meals, refrigerators and toilets were installed. Five-star quality several tens (even hundreds) of metres high! "Video circuitry was connected in the cabins", continued Bernard le Gouriérec, commercial technician. "This improves safety and the precision of manoeuvres at ground level, while making work possible in case of fog. Every measure was taken to ensure that this construction site and our collaboration with Eiffage should be a success. To this end, we have even based a permanent maintenance team on the site". This is essential for erecting monsters like the crane



### Potain S.A.S. is...

- A company created in 1928 by Faustin Potain
- The world leader in crane manufacture
- A subsidiary of the American group Manitowoc
- 1.3 billion euros turnover for the group in 2002
- 2,200 employees throughout the world

on pier P2: 264 metres in overall height, weighing 404 tons and equipped with a winch with more than a kilometre of cable. A machine that – like the six others – allows loads to be lifted and positioned to the nearest centimetre. What more could you ask for? ■

\* Above 72 kilometres an hour, the cranes are put in a weather vane mode and the work is stopped.

Millau inhabitants

## Didier Auriol, rally driver

Even if his passion takes him to a good number of countries across the world, Didier Auriol is no less



faithful to his Millau origins. Crowned world rally champion in 1994, he considers the viaduct under construction with a clear head. "This motorway is essential, and a solution for crossing the gorges of the river Tarn had to be found. The bridge as designed takes the preoccupations expressed by the inhabitants of the region into account. Among all the projects put forward, its route is the one furthest from the town, which limits to a maximum any eventual inconvenience to the residents. I believe that the economic and tourist benefits for the region will make themselves felt above all in summer. It will be simpler to cross the town, and people will find it easier to visit the area. They will be fascinated by the grandeur of its landscape. In the low season, the sporting facilities of the town should be promoted and a major event and activities should be created to attract visitors to our area". ■

Visits

# The viaduct is drawing crowds

The figures speak for themselves. More than 1,200 visitors were counted on some Sundays last March at the Cazalous welcome area, while many hundreds make the detour every day. In all, more than 70,000 people have already come to admire the construction site and its natural setting. They come for the most part just out of curiosity, but there are also professionals from the BTP building and public works sector, or school groups on study outings from throughout France. Visits to the construction site should be reserved several months in advance.

### Two ministers on the construction site

Among the people in the public eye, two French ministers have recently made the journey to Millau. Gilles de Robien, Minister of Transport, showed a particular interest for his part as much in the construction itself as in the safety measures that have been planned for when it is in commercial operation from 2005. As for Jean-Paul Delevoye, Minister of the Public

Function, State Reform and Town and Country Planning, his visit last February 10 was the opportunity for announcing the long-awaited appointment of "Mr. Viaduct". It is therefore Yves Poss, engineer for Rural Communities and the Forestry Commission, who will co-ordinate all the development projects and accompanying measures connected with the viaduct: design of the Brocujouls motorway rest area (near the north abutment), creation of a centre for interpreting civil engineering structures, preservation of the roadways created specifically for the construction site, installation of architectural lighting for the viaduct, etc.

### From the source of the Danube to the gorges of the river Tarn

A lesson on the geography of the Causses, a lecture on the traffic problems in the region and on the necessity for constructing a bridge over the river Tarn: the 22 students from the college of Donaueschingen, a small town in Germany near the



German fourth-grade students on a visit to the construction site as part of an exchange with the Marcel Aymard College at Millau.

source of the river Danube, were well prepared for their tour of the construction site. Visiting Millau as part of an exchange with a fourth-grade class from Marcel Aymard College, they were all impressed. For Oliver, 14 years old, "it's a project which represents a huge amount of work", whereas for Stefan, he "finds it difficult to imagine that the bridge will be twice as high" as what he can see now. However, they both hope to cross it one day... when it has all been finished! ■

Internet

## The viaduct weaves its web

The Millau viaduct with a few clicks of a mouse! For some months now, you have only to access the net to obtain all the information on the project conducted by Eiffage: an overall presentation of the viaduct, its history, the participants, progress of the work, construction site news, video of the month, etc. There are eight index headings in total, some of which are updated every week with the latest news. Therefore, if you want to know in real time – or almost – how far the construction of a pier has progressed, or which are the latest personalities to have visited the site, you only have one address to remember:

<http://www.viaducdemillaeiffage.com>. "It's equally possible to leave us an e-mail address to receive information automatically about everything new on line", points out Camille Petit, webmaster of the site. "Moreover, we try to reply within 24 hours to the questions sent to us by surfers on the web".

Very construction orientated for the time being, the site will expand gradually to include the future users of the viaduct. However, in the meantime, several developments have already been planned: a FAQ (a question and answer forum), a

photo gallery as well as a virtual visit of the structure for all those who do not have the chance to see the construction for themselves. ■

### The number of the month

6,500: this is the number of connections to the official website of the Millau viaduct in February 2003.



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 4, rue de la Mégisserie  
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