

viaduc

ÉDITÉ PAR LA COMPAGNIE EIFFAGE DU VIADUC DE MILLAU



Rendezvous in July 2004

"The construction of the piers is complete. Even if this does not mean the end of the "concrete" site because the toll barrier has still to be built, it is normal that everybody should be delighted. The deck can now be launched its full length. At the beginning of July 2004, we will all get together again to celebrate the final welding of the 36,000 tons of steel above the river Tarn!"

Marc Legrand, general manager of the Compagnie Eiffage du Viaduc de Millau

Great pride

"We are all very proud of this construction site: we kept to the timing and, above all, we did not have any serious accident. We have thirteen months left to finish everything before the inauguration. A multitude of tasks – less visible but just as important – have still to be completed. I should like to pay tribute to the tenacity of all the Eiffage TP and Eiffel teams".

Jean Guénard, chairman of CEVM and assistant general manager of Eiffage TP

From left to right: **Marc Legrand**, general manager of CEVM, **Jean Guénard**, chairman of CEVM and assistant general manager of Eiffage TP, **Jacques Godfrain**, Member of Parliament and mayor of Millau, **Jean-Louis Monniot**, sub-prefect of Millau, **Jean-Pierre Martin**, Eiffage TP project manager.

An unforgettable spectacle marking the end of the construction of the piers.

A son et lumière evening

Last December 9, in spite of the winter cold, the atmosphere on the viaduct construction site was particularly warm. More than 400 people had arranged to meet there to celebrate the end of the construction of the piers.

When the first Bengal lights lit up the viaduct piers, all eyes turned instantly towards them in amazement. On the Creissels road, further down the valley from the structure, the cars ground to an immediate halt. An

unforgettable spectacle – with the full moon and a starry sky as a backdrop – during which the fireworks lit up the whole river Tarn valley for several long minutes. The highlight of the display: the green laser beam which, by connecting the north and south sides of the structure, gave the impression for a few seconds that the two halves of the deck had been joined together.

The end of the construction of the seven concrete piers and the two abutments constitutes a turning point in the life of the Millau viaduct construction site. It was "mission accomplished" for the "concrete" teams, a year and a half after the first "lifts", and a few weeks ahead of schedule. A complete success, both on the technical and human

levels, with, to boot, a world height record for pier P2 (245 metres), without any serious accident having occurred to dampen the performance.

continued on page 2





VIADUC DE MILLAU - 8 DECEMBRE 2003
PHOTO LIAMING POUR EIFFAGE

A lump in the throat

"I shall always think of Millau as a very fine construction site... and the celebration this evening is really superb. We are all of course very moved to see this firework display, and it obviously brings a lump to one's throat to think it is finished. But that's the way with construction sites!"

Daniel Guille, site manager for pier P2

continued from page 1

An answer to every problem

Even if he finds it hard to conceal his emotion, the Eiffage TP project manager, Jean-Pierre Martin, modestly displays his joy at having brought the raising of these seven concrete needles to a successful conclusion. A professional who does not hesitate, during the compulsory speech, to confide in the 450 guests gathered under the immense marquee erected for the occasion. A few phrases that reveal all the pressure which he had to face together with his teams. "In fact, I was concerned by the sheer number of problems requiring solutions", he confesses. "Would the ground be stable enough? Was the concrete formula the right one? Would the technical research laboratories provide the

plans on time? Would we be able to find suitably qualified employees? Would the formwork prove to be sufficiently effective? As the work advanced, we found answers to all these questions. If two years after the first stone was laid, the piers and the abutments are finished, it proves our choices were the right ones!" ■



The adventure of a lifetime

"This evening's celebration reflects the way things went on the construction site: magnificent. Now, it is up to Eiffel to finish their work. We have overcome a good number of technical difficulties and half the launching operations are already completed. We had never before worked on such a construction site over such a long period and with so many outside participants. This project has federated all our teams".

Jacques Huillard, chairman and managing director of Eiffel

Concrete

The final stretch

The year 2004 promises to be a busy schedule. "The spectacular aspect of the construction site is behind us, but we are now entering a more complex phase: the installation of the viaduct instrumentation (sensors, optical fibres, inclinometers, etc.), electrical networks, signalling, the lighting and of course the toll barrier and the

technical control centre", explains Jean-Pierre Martin, the Eiffage TP project manager. The time has also come to dismantle the infrastructures that were used to erect the piers. The self-climbing formwork has already been taken down, as well as the cranes, except those on piers P2 and P3 that will stay up until the spring. By the end of March,

the two concrete mixing plants will have been removed from the site, as well as the hanger under which the steel reinforcements were assembled. It will then be time to remove a large number of the site bungalows. As for the restoration of the landscape around the support towers and piers, "it is under study", declares Jean-Pierre Martin. ■

A construction site and the workforce

A microscopic walkway between earth and sky on top of pier P3, at 221 metres.

"I have taken part in all the stages of the construction of this pier, from the foundation slab up to the top. I regret that it is ending and that there is not a second site like Millau! The atmosphere here has always been very good".

José Barbora Amorin, 32 years old, formworker.

"I arrived here in March 2002. At the beginning, since we were not used to working with self-climbing formwork, we had to find the right way round it! Today, it's over... but I am going to continue my career with Eiffage".

José Rodrigues, 58 years old, formworker.

"During the whole construction of pier P3, I was responsible for the lift. I received specific training for

The site's acrobats



How can one install the ladders inside the piers (to carry out eventual rescue operations on the viaduct) or the lengths of cable needed for the electrical and telephonic networks and the lighting? How can one work on the outside walls to remove the clamps, diabolos or the other "ironmongery" used for their construction? There is only one solution: call upon the professionals of aerial work. As both mountaineers and acrobats, the six employees of the Imbert Company are specialists with ropes, harness... and weightlessness! Fear of heights? They do not know what it is! "We go to all the areas that cannot be reached by the cranes, the cradles or the scaffolding", explains Florent Souyri. "At the beginning, one is a bit apprehensive. You have to let yourself go by giving complete trust to the equipment". Above all, by having a strong stomach. ■



it, and I liked the job a lot. Millau was my first construction site. These past eighteen months have enabled me to acquire a unique professional experience, and I should like to stay in the field of building and public works (BTP)".

Bachir Sadouni, 21 years old, lift operator. ■

The toll barrier: a voussoir every two days

Begun last October, the construction of the 53 voussoirs forming the canopy of the toll barrier has reached cruising speed: a new section is poured every two days. Constructed in BSI Céracem®, very highly technical concrete, each of them has its own unique, slightly warped shape. Once assembled, they will make the canopy seem like an immense sheet of twisted paper. At the end of December, sixteen voussoirs had been created. Everything should be finished by the end of April 2004. ■

Voussoirs: impressive dimensions for the toll barrier canopy.



From piers to support towers: advancing under control

With the success of the first ten launches of the deck out of the eighteen planned, the Eiffel teams are keeping to schedule.

A close-up of a construction site working flat out.

Step after step, metre by metre, the gigantic steel ship, which made its appearance last March on the Larzac side of the valley, is continuing on its giant's journey in the Millau sky. With no longer anything capable of hindering its forward advance, the south deck seems to be swallowing up the piers and support towers one after another – inexorably. Its bright-red leading beak points to the goal to be reached, like a finger stretched towards the other side of the valley,

towards its "brother", the north deck. The more time passes, the faster its cruising speed. "We have very appreciably increased the rhythm for assembling the elements of the deck, the side bearing sections and the central box-girders", stresses Jean-Pierre Gerner, the Eiffel director of works. "At the start, we had programmed a launch every six weeks. Today, we carry out a launch every month. Just imagine what that represents: 171 metres in four weeks... Nobody had dared to imagine that we could go so fast!"

At the end of December 2003, ten of the eighteen launches had been completed, without any significant problem occurring to hinder the steelwork. So, just routine? The word ruffles feathers, just as it would do in the space industry with every rocket launch. On the construction site, however, they acknowledge that they are now very familiar with the



assembly and launching procedures for the deck. The principle unknown factor during the coming months is the weather. Ice, wind, snow or rain can hold up everything from one

minute to the next. "The floods in the south of France delayed the convoys bringing the box girders from Fos to Millau", Jean-Pierre Gerner recalls prudently. Fortunately, the

situation improved after a few days and we had enough elements in reserve to be able to continue our work. But we are never safe from unforeseen events of that type!" ■



Like a mushroom!

To grow like a mushroom! The expression applies perfectly to the temporary support tower Pi 2. At the rate of 12 metres every 24 hours, the Eiffel teams made it a point of honour to give it its final height (more than 170 metres) within a matter of days. Their goal? Finish everything by Christmas, and they managed it! In addition, a new world record!

Checking up on everything

The temporary support tower Pi 7 goes unnoticed by the visitors. It is nothing compared to its big sisters, which rise to a height of more than 150 metres in the middle of the valley. Although only just higher than the vegetation growing next to the C8 abutment, it is however the most sensitive of them all. Surprising, but logical. Because of its position, particular demands are made on Pi 7, especially during the launches of the deck. However, its small size makes its structure extremely rigid. A lack of flexibility that means that it has to be checked permanently. "The top of the support tower can not withstand more than a few centimetres movement", declares Hervé Lançon, technical director of the Sites Company, specialised in instrumentation for civil engineering structures. "A laser range-finder placed on top of the support tower permanently reports its position".

Permanent surveillance of the accelerometers, windspeed indicators, extensometers and other measuring instruments installed on each strategic element of the viaduct.



The attention given to Pi 7 reflects the importance given to the safety of the construction by those responsible for the worksite. Nothing can be left to chance while it is being built. Everything has to be designed to be able to analyse its behaviour once it is in service. Consequently, the piers, deck and pylons bristle with accelerometers, windspeed indicators, extensometers and

other measuring instruments. "The launches of the deck are subject to intense surveillance", continues Hervé Lançon. "Accelerometers are placed in strategic positions to monitor the vibration phenomena which might affect the steel structure. In addition, sensors evaluate the changes in temperature that might cause deformations of the deck. Also to be noted is the

installation of a windspeed indicator, at the far end of the south deck, which records the diffusion of ultrasounds in the air as it moves. It also has the immense advantage of registering vertical windspeeds likely to lift up the structure during the launches".

A good number of these instruments will stay in place when the viaduct is put into service. Others will be added to complete the existing range. The movements of the deck, at the level of the expansion joints on each of the abutments, will therefore be measured to the millimetre. As for the stay cables, they will be permanently checked, and their rate of ageing closely followed. Therefore, you can rest easy. When you cross the river Tarn by car on the A75 motorway, you can be sure that the steel and concrete giant you are travelling over is in perfect health! ■

An ambition for seven departments

The "La Méridienne" association was created in 1986 with the intention to promote the transformation by the French government of the N9 trunk road between Clermont-Ferrand and the Mediterranean into a modern structure. "At the time, we didn't even imagine the creation of a motorway", recalls their president Jean Julhe. Today, with more than 500 members, the association brings together the elected members from the communes of the seven departments crossed by the A75 motorway. Their ambition is to make this major trunk road a special means for promoting inter-regional development, not only from an economic point of view but also for culture and tourism. Already the potential for developing these fields is proving considerable. "Road traffic has grown ten times over the last fifteen years", explains Jean Julhe. "The opening of the Millau viaduct will attract a large number of additional vehicles to use this motorway". Besides, of course, creating important local business. ■

High points

Before the viaduct is put into service, fixed by contract for January 10, 2005, high points will mark the year 2004.

- **June:** last launching of the south deck. Between January and June, eight launches have been planned, in other words one every three weeks.
- **Early July:** welding together of the south and north decks at 250 metres above the river Tarn.
- **Summer:** erection one after the other of the last five pylons and fitting of the stay cables. For information, it takes a day to raise an 87-metre-high pylon to a vertical position.
- **End October:** completion of the toll barrier and the roadway.
- **December:** delivery of the viaduct. ■

Steel muscles!

They are almost invisible from the ground on the construction site, but they fulfil a vital function for each deck launching. What are they? The transfer jacks. There are 64 of these pieces of apparatus, secured on top of the piers, the temporary support towers and the abutments, allowing the thousands of tons of the steel deck to be advanced over the void.

Each transfer jack is made up of a frame that supports the deck. There are two diagonal-section chocks inside the frame. The lower one, known as the angled chock, allows the deck to be lifted with a force of 2,000 tons. The top one, referred to as the slide, permits the deck to be "translated" forward with a force of 120 tons over a distance of

600 millimetres. Hydraulic jacks connected to a high-powered, central hydraulic station drive each chock. A microcomputer on each pier or support tower relays instructions to the central hydraulic station. Each pier or support tower responds to a central computer, installed in the launching control centre. The entire technique (transfer jacks, hydraulic controls and associated computer technology) was conceived and developed by the Eiffel engineers, Marc Buonomo and Jean-Pierre Gerner. Without the aid of this system, installed for the first time on this viaduct, it would have been impossible to move the deck that weighs, on the south side, more than 20,000 tons. Indeed, the traditional systems for pushing decks could not have been used because of the great height of the piers and support towers.

The idea of the transfer jack was adapted to the loads, calculated



It is with the help of transfer jacks that the thousands of tons of the deck can be lifted and moved forwards.

and designed by the Greisch research laboratory in Lieges. The Maurer Company, which developed special Teflon for them, manufactured the transfer jacks; all the hydraulic and computer systems were designed by the research centre of the Enerpac Company based in Madrid.

Six hydraulic jacks, with an overall power of 3,600 tons, are installed under each frame of the transfer jacks. "These hydraulic jacks serve as "bogies" for the complete structure", explains Fernando Cendoya, Enerpac representative on the viaduct construction site. "They serve to compensate any deformations, and to stabilise the deck on the piers and support towers. With

the help of this patented system which combines mechanical, hydraulic and computer technologies, the deck is moved forward on its supports at the speed of 7 metres an hour".

Multiple sensors are fitted to the transfer jacks. They transmit readings every second to the central computer: the position of the transfer hydraulic jacks, the pressures, the positions of the ends of the slides, etc. The computer centre manages these readings and co-ordinates the action of each of these steel muscles by remote control. They all have to work in perfect synchronisation. It is the sine qua non to ensure the success of the launchings of the deck. ■

Discovery

Ready to work more than a hundred years...

The installation of the stay cables was entrusted to the Freyssinet Company, famous worldwide for specialised civil engineering work.

A stay cable anchorage point.



The stability of the Millau viaduct could have been jeopardised simply by drops of water. Incredible but true! The explanation however is quite clear: the path taken by rainwater running off along the stay cables changes their geometry and the way they catch the wind, causing vibrations as a result which attain an amplitude of up to two metres! The problem was resolved by moulding a thin helical strip on the outer casings. This has the effect of "breaking" the flow and causes the water to fall in drops to the ground before it can run down the stay cable. This particular example demonstrates the extent of the attention given to one of the most visible structural elements of the viaduct: the stay cables.

Each pylon will be fitted with two spreads of eleven stay cables positioned along the centre-line of the viaduct. Each cable is capable of withstanding a tension of between 1,500 to 2,500 kN, depending where it is fixed to the deck: the further they are anchored from the pylon, the greater the forces to which they are subjected. "But they will only be subjected to 50% of their capacity during their projected service period", stresses Manuel Peltier, project manager for Freyssinet, the world leader for cable-stayed structures. "Each stay cable is made up of a collection of 15-millimetre-diameter strands (between 55 and 91), which are themselves made of seven 5-millimetre steel wires". In all, 1,500 tons of cable

will be installed on the viaduct.

The strands will have a triple protection against corrosion. Once they have been galvanised, they will be encased in polyethylene and their interstices injected with petroleum wax. The outer casing has moreover received special treatment against damage caused by ultraviolet waves. "The stay cables have been subjected to a large number of tests in different laboratories, particularly regarding their waterproofing and resistance to strain", continues Manuel Peltier. "Traffic, expansion, vibration, wind... everything was simulated for millions of cycles corresponding to the different phases in the life of the viaduct. The result was that no damage to any of the strands was recorded. The material supplied conforms to the latest ruling legal requirements, and its life expectancy is designed to be in excess of 100 years!" ■

Eiffage at a glance

Perpignan-Figueras

Eiffage and their Spanish partner ACS have been selected as concessionaire-constructors of the 45 kilometres of the high-speed railway line which in five years time will link the railway networks of the two countries. An undertaking costing three times more than the Millau viaduct.

Wittfeld

Appia, the road construction branch of Eiffage, has acquired this German civil engineering and railway construction company with 600 employees in the northwest of Germany.

Electrosur

Based at Albacete in Spain, this company with 620 employees is now a subsidiary of Forclum, the Eiffage electrical installation branch. ■

Safety

Goal: zero accident

On the viaduct construction site, the safety notices are omnipresent and apply to everybody. Without exception.

Is it dangerous working at a height of more than 200 metres? Visitors to the viaduct site regularly ask this question. The answer is clear: no, not more so than on a "normal" construction site provided sufficient investment is made. No death or serious accident has been recorded since the beginning of the work. Moreover, when it comes to safety, just as much for Eiffel as for Eiffage TP, the cards are on the table. "The most serious accidents

Christophe Mazars, responsible for accident prevention for Eiffel.



we have had the cause to regret are a fractured foot and a broken rib", confirms Jean-François Vidor, accident prevention and safety officer for Eiffage TP. "Ocular problems (irritations, spark projections) are the most frequent, particularly with the welders", adds Christophe Mazars, responsible for accident prevention for Eiffel. They both agree on one point: nothing can ever be taken for granted when it comes to safety. Instructions on the subject must be repeated constantly, from the first to the last day of work. The goal remains zero serious accidents.

Keeping an eye on everything

Work procedures were examined with a fine-tooth comb by those responsible for accident prevention and safety on the construction site. "Index cards give the details and the order in which the tasks should be carried out", explains Jean-François Vidor. "Each of them indicates the risks involved and the way to avoid them. Before any new

phase of the construction site begins, a meeting is held when the specific safety instructions are clearly spelled out to all the workers concerned". The essential element in accident prevention is the commitment of all the employees. A welcome booklet and equipment for self-protection are given to all employees before they join their teams. "Every member of staff is responsible for respecting the safety instructions the second he puts a foot on the construction site", stresses Christophe Mazars.

The two safety officers permanently do their rounds on the site. A missing barrier, badly adjusted protective clothing: they keep an eye on everything. They can call work to a halt, for the time it takes to bring safety measures up to standard. In addition, if a storm approaches within 15 kilometres of the viaduct, the warning from Météorage is immediately relayed on the construction site siren. No question of taking the slightest risk. ■



Jean-François Vidor, accident prevention and safety officer for Eiffage TP.

Opinion

"The closing phases of a construction site are always delicate to manage. Disassembly procedures are often less well co-ordinated in the work, concentration levels drop and the risk of an accident increases. This aspect is well accounted for by those responsible for the viaduct, with whom it is possible to work completely openly... and to ensure the safety of all".

Gérard Héréty,
safety controller,
CRAM Midi-Pyrénées.



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