AROUND THE ROCKS

PRECASTING IS TAKEN TO NEW LEVELS IN BUILDING FRANCE'S LONGEST VIADUCT USING SOME OF THE WORLD'S BIGGEST KIT

BY MARK HANSFORD

Shark gun? Check. Typhoon shelter? Check. Scuba gear? Check.

Ravings of a madman? No, just the checklist for anyone heading out to work on France's latest *grand projet*.

Grand it most definitely is. The *projet* in question is to create France's longest viaduct – indeed one of the world's longest segmentally-launched viaducts – using one of the world's longest launching gantries and what is unquestionably the world's largest offshore overhead travel crane.

But this is France. So where do the sharks and typhoons come in? Well, this viaduct is in – or, to be more precise, around, the northern tip of Réunion Island, a French department in the Indian Ocean a (long) stone's throw from Mauritius.

Réunion is an intriguing place. Home to one of the world's most active volcanoes, it is very French – there are a lot of strikes and an awful lot of politics – yet set amid the Indian Ocean; it is a beauty and a beast.

Its seas, in southern-hemisphere mid-summer, are calm and inviting, but no-one dare go in, as they are swarming with sharks. The breeze is gentle and cooling, yet can, at a moment's notice, turn into a vicious, destructive typhoon. And its geography is steep and undulating, but can, again at moment's notice, wreak havoc on motorists using its main road with massive rock-falls from the unstable volcanic cliffs. It is this road, lapping perilously around the island's northern coast and linking its main town with its main port, that the *grand projet* is there to replace.

And it is quite a team doing the replacing: a four-strong joint venture (JV), the two main partners are French contractors Bouygues and Vinci – both with *grand projet* experience aplenty. But nothing quite like this.

The project is hard to describe. A bypass of a coast road routinely struck by massive rockfalls is the gist.

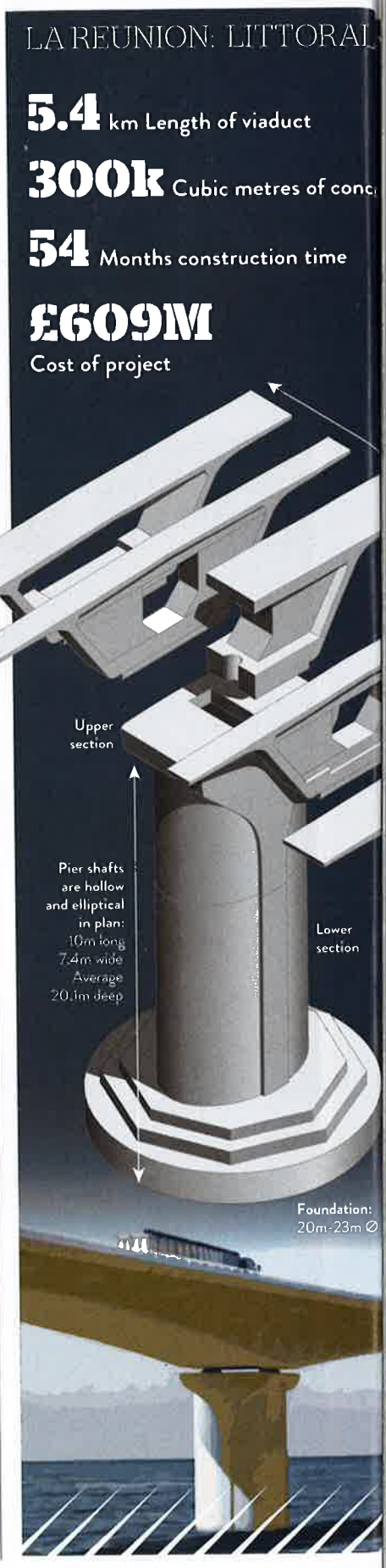
But how do you bypass a coast road hemmed in by sheer rock faces on one side – rock faces that are protected from even the smallest intervention by the presence of nesting rare birds – and the ocean on the other?

Well, you build the bypass out

KEY FACTS

5.4km
Length of viaduct under construction

6.7km
Length of causeway being constructed



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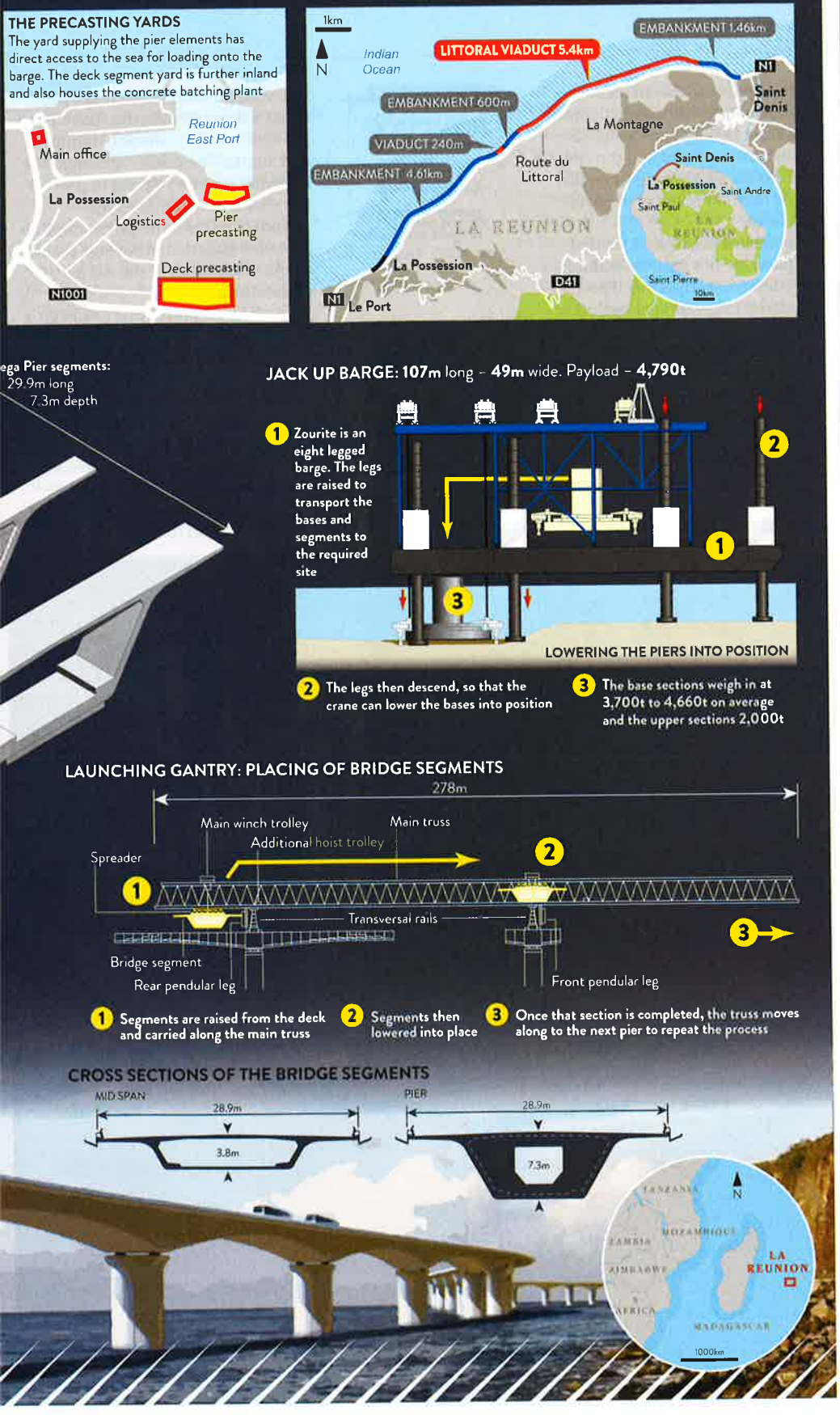

> **By precasting in land facilities, it makes work more accessible to local manpower**

in the ocean, out of rockfall range. Obviously. And that is the *grand projet* – the New Coastal Road – curving gently round the coastline over a length of 12.5km between the towns of Saint Denis and La Possession. The link consists of the 5.4km long Littoral viaduct – France's longest viaduct either inland or at sea – the much shorter 240m Grande Chaloupe viaduct and a series of causeways 6.7km in length.

It is almost all government-funded, with 49% coming from the French government and 42% from Réunion's regional administration. The rest is coming from the European Union Regional Development Fund.

Others are doing the causeway, and perhaps the less said about that the better as it is running a year or more late because of delays in getting planning permission for a massive quarry needed to mine the rock to form it. And Eiffage has already built the short Grande Chaloupe viaduct. But the most challenging engineering is on the Viaduc Littoral, a €715M (£609M) project that is uniting French contracting powerhouses Vinci and Bouygues with Vinci subsidiary Dodin Campenon Bernard and civils contractor Demathieu Bard.

It is impressive, and the genius lies in how the contractor has listened to the client from day one. The key decision it made was to opt for an almost entirely precast concrete solution.

JV project managing director Francis Guinchard explains: "The tender documents specified that, for corrosion control reasons, the viaduct was to be all concrete – a prestressed, post-tensioned balanced cantilever sitting on piled foundations. But in the original bid we were allowed to propose some alternatives – just no steel."

That alternative was to precast as much as possible.

This part of the project technically comprises seven independent viaducts, each 770m long. Together they sit on 50 bridge supports – two abutments and 48 piers.

At deck level, the contractor has

> **We have got rid of all the piles and introduced our own method of construction**

changed little from the original design, other than small changes being to modify the profile of the webs a little and to add a little transverse post-tensioning to do away with transverse ribs, to simplify the prefabrication process. But below that, everything has changed.

"The superstructure is very much like the tender design," explains Guinchard. "The difference is we have got rid of all the piles and introduced our own method of construction."

With the foundations bearing on sand or rock, the client's engineer Egis envisaged a mixed approach, using spread foundations for half the piers and supporting the others on groups of four deep piles, 4m in diameter.

But these are all gone, replaced with massive 20m to 23m diameter precast concrete gravity bases.

Going for precast gravity bases was a big win for the client. Concreting in a marine environment demands specific skills that the local workforce lack. This would inevitably have meant bringing in labour from abroad (or at least mainland France).

Concreting in onshore precasting yards meant local skilled labour could be used – a huge plus for those in charge of an island where the unemployment rate runs at about 25% overall and around 50% in young people.

"By precasting in land facilities it makes work much more accessible to local manpower. There is experience on the island for concreting works, but not so marine works," explains Guinchard.

Now, around 700 of the total workforce of 800 will be local.

It was a laudable socio-economic move, but there were other, more pragmatic engineering reasons. One was the better overall quality of the finished product that precasting typically offers. This is particularly important here, given the harsh marine environment and the client's demand for a 100 year design life.

And then there are ecological concerns.

Guinchard acknowledges that the piers are not entirely without environmental impact as there is a dredged excavation at each pier location to remove sand, gravel and loose boulders, but, he stresses, there are no piles and there is no concreting at sea, which carries spillage and contamination risks, which could damage the local marine environment.

"At tender, the client was interested to know what kind of measures the contractor would take to protect the environment," said Guinchard. "That's the corals on the seabed and the sealife itself – whales, dolphins and sharks," he adds. "Although the lobbying is not so strong to protect the sharks," he notes wryly.

And, of course, the precast option provided substantial savings thanks to the elimination of the deep foundations.

So all in all, precasting has been good move. But the decision was one that was going to present a real challenge to Bouygues' and Vinci's lauded "methods engineering" teams to come up with a buildable solution.

It was already going to be complex. This is one wide viaduct – needing to accommodate a dual two lane carriageway road, along with the potential to add footpaths, cycle

Below: The existing coast road will be replaced
Right: The 278m long launching gantry is one of the longest ever built

lanes, and even two tram lines.

It is also a relatively tall one, as the deck must be clear of the typhoon-prone sea by 20m to 30m.

So all in all that means quite a lot of concrete – 300,000m³ in total– to precast and manoeuvre into position.

The solution was to invest in some serious kit. We are talking about one of the largest launching gantries ever bought and assembled to install the prestressed deck segments. We are also talking about one of the largest jack up barges ever built to accommodate the world's largest offshore overhead travel cranes.

"Everything here is huge," observes JV terrestrial work managing director Jean-Luc Bouchet, who is in charge of operations on the viaduct.

Beasts seems to be the general word used to describe them. The size of the barge in particular is unprecedented. But there is a logic to it.

"Because the sea can be quite rough, to be operational 85% of the time, the marine works would have to be of a certain size anyway so it made sense to maximise capacity and make the elements big," says Guinchard.

"But then you have to be able to manoeuvre them [the elements] on land, so you reach some sort of compromise," he explains. That compromise is to split every pier into two elements – am 10m tall base section with the 2.4m thick, 20m to 23m diameter precast concrete gravity base, plus a 10.8m tall pier section

Because they have to withstand swells and ship impacts – the biggest design load is a 3,000t ship impact applied 4.2m above sea level – the piers are hefty: the pier shafts are hollow and elliptic in plan, 10m long by 7.4m wide and 1.1m thick.

The base sections weigh in at 3,700t to 4,660t and the upper sections a not immodest 2,000t. And so the barge to transport and install these sections was clearly going to be a hefty beast – and it is.

The eight-legged barge is called *Zourite* – the local Créole word for a small octopus, which is a local delicacy. And at 107m long, 49m wide and with a maximum payload of 4,790t is one of the largest ever built by Polish shipbuilder Crist. The crane that then does the manoeuvring was built by Enerpac and is claimed to be the world's largest. All in all it cost the JV £84M – more than 10% of the contract value. "It is quite an investment – a gamble almost," says Guinchard.

But it looks like the gamble will pay off – as it is certainly being put to good use, doing more than just landing the piers. "If the jack up is doing the piers we thought: 'let's get it to do the deck segment that sits on the piers too'," he says.

Marine works lead civil engineer Xavier Loye adds: "It is a very good thing for the site to have the first segments preassembled."

"And then we thought: 'if it is going to do that, why doesn't it also do the first two segments either side as well?' We call it the 'mega' pier segment," he says. "Having those segments erected by barge means that the launch gantry is only doing the identical segments." At 2,500t, this megapier segment is also a massive piece, and is tricky to manoeuvre too with its near 30m width taking up almost the full

KEY FACTS

25%
Unemployment rate on Réunion

700
Number of local jobs created by the project

> **"Once we made the choice to go precast, the question was how big can we go?**

"The programme is to do two piers per month and we are getting much faster than we were at the beginning

working width of the platform.

Then there is the launch gantry, supplied by Italian steel fabricator Cimolai. It is no small thing itself, measuring 278m long and weighing 2,400t. The gantry consists of a launching beam supported by two lattice towers and a front leg. During a typical sequence of cantilever construction, one of the lattice towers rests on the cantilever under construction, the second its previously built neighbour and the front leg rests on the next pier.

Deck segments are hefty – 4.1m long, 29.9m wide and varying in depth from 7.3m at the piers to 3.8m at mid span. They are also heavy – the deck slab itself has a variable thickness from 300mm at the overhang extremity to 600mm at the meeting of the web, before finishing at 370mm in the middle of the central slab. Web thickness is 650mm.

But this sizeable rig's main asset is its ability to lower two of these hefty segments into position on either side of each pier simultaneously – ensuring the viaduct remains totally balanced at all times.

And as an added bonus, the depth of the launching beam means that the segments travel entirely within its lattice framework, meaning that there is room for a secondary hoist to transport materials along the underside of the beam. The two can pass each other, allowing overlapping of tasks and much more efficient operations.

"And that is important as the target is one complete cantilever – 120m comprising 28 segments – in one week of 15 shifts," says Guinchard.

Amazingly, the launch gantry came flat-packed with no members more than 12m long so it would fit into shipping containers. As a result the

OPERATING 'ZOURITE', THE JACK UP BARGE

"Zourite" has several jobs to perform at each location. Clearly the main role is to drop the piers into place, in their three sections – the gravity base, the pier head and the mega pier segment.

This is done using the barge's 4,790t capacity crane, which first slides the sections along the deck on skids and then lifts them into position at the front of the barge. Once there the sections are lowered into position using a fully computer-controlled process. which uses algorithms to predict the movement in the wind, waves and currents and adjust the lowering accordingly.

"Everything we do is predicted by the computer," says Loye. "So it is really an automated process."

Clearly this positioning is most critical with the base section, and it is not as straightforward as it sounds. Unlike offshore wind turbines, the verticality required means there has to be more assurance that the base will lie flat. Attention must be paid to the horizontal positioning too, as the bridge deck must land in the right place.

"There was a big debate about this," says Guinchard. "When you do the footings for gravity bases on offshore wind farms you can do it to the tolerance required using just a gravel bed. But turbines have devices to correct any off-vertical installation – and of course the placing need not be so precise.

So rather than drop the base directly onto a prepared seabed, the jack-up lowers the base to within 400mm – with a 200mm tolerance – using special attachments that clamp on to the base at four locations around its perimeter.

At this point two significant things happen.

First, the exact horizontal location of the base can be checked and corrected using jacks contained within the clamp attachments.

"A lot of brain juice has been spent on this, and 80mm tolerance is specified at the top of pile cap. But right now we are doing it to within 1mm," laughs Loye. "It's working well."

Concrete, batched on the barge, is then pumped down through ducts cast into the base and into six to eight heavy-duty plastic bags attached to the underside of the base. These inflate with the concrete, filling voids and levelling out undulations.

"So far so good," says Guinchard.

The next step is to drop into place the pier head. There is then a pause, usually only until the next day, while the jack-up returns to port overnight to collect the 2,500t mega pier segment. This is challenging as there is barely 1m of leeway either side of the barge to manipulate the segment into place. But once this too is lowered onto the bearings, engineers on the barge move on to the next stage of operations – a stage that all agree needs a little re-engineering.

That is because it is a fiddly job glueing the two pier sections together with a 1.5m high cast insitu concrete stitch. It takes at least a day, and that is a day when the barge is idle. The project team is currently considering an alternative way to get this work done, allowing the barge to crack on with its real purpose and buy some breathing space from the deck gantry team.

> **It is a big Lego kit. It is very clever but looks very simple**

whole thing took the whole of last year to assemble in the quayside site compound.

"It is a big Lego kit," observes JV beam launcher lead civil engineer Thomas Silvestre. "It is very clever but looks very simple."

The barge and the gantry are now on site, and those responsible for running them are quickly getting up to speed.

It is early days, with three piers landed and one complete span nearly complete, but the mood is very positive.

Supplying these pier elements are two precasting yards. The yard supplying the pier elements has direct access to the sea for loading onto the barge and one for the deck segments. The deck segment yard is further inland and also houses the concrete batching plant and, even at 8ha, is, in Guinchard's words: "as full as an egg". Deck segments are transported to the quayside by road.

Work at these too is also in full swing.

Indeed, the slowest-paced activity at the moment is pier installation from the barge. It puts the team in charge firmly on the critical path, but it is aware that this is a sensitive operation and that it must hone its technique.

"The first pier was all about validating all the technical details," says Loye. "And we used divers a lot for checks."

The real caution then comes when moving the barge from one location to another.

"When we are jacked, and with eight legs, we are not moving at all," explains barge captain on board Laurent Auvinet. "Once afloat it is different and we cannot risk hitting the piers. With the first one we were very sensitive, we waited for the best moment."

There is understandable caution from both, but it is nevertheless frustrating to those looking on from the bridge, a stone's throw away.

Local labour is employed in the two huge precasting yards

"The programme says we have 371 days left," notes Bouchet. "But if the barge doesn't speed up we'll still be here in four years," he wryly observes.

The 54 month construction contract began in January 2014, and completion is scheduled for July 2018.

Now, reassured about the stability of the barge, how the system is working and, more importantly, how accurate the dynamic positioning system is when manoeuvring, the barge team says the pace is now quickening.

"Now we see it is stable, we are speeding up. The programme is to do two piers per month and we are getting much faster than we were at the beginning," says Auvinet.

"The first pier was about validating. For the second one we made some changes and simplified things, and on the third one we can already see we are getting faster," agrees Loye.

And as to the friendly pressure from those on the deck gantry team he has a riposte. "We did deliver it to its launch location, which is why we have lost some time," he says.

He is half joking, but that was actually a hugely significant moment. The gantry was planned to be launched from shore via the newly-built causeway – but with a section of the project running late, an alternative means of delivering it to the launch location was found in the shape of *Zourite*. It prevented a massive delay.

The good news for the programme is that the team has not yet lost time due to typhoons – although they are heading into peak typhoon season. Special procedures are in place should a typhoon be forecast. The jack up barge heads to port and all other vessels head to typhoon shelters. If there is no time for that, the barge is designed to cope.

"If we can't to port, we jack up as high as possible to get above the swell," says Auvinet. That is crucial. "Because if we are hit by the waves, it is possible the barge could capsize."

They are ready though. "We have not had one yet, but we have done the test." **N**