JACQUES CHABAN-DELMAS VERTICAL LIFT BRIDGE IN BORDEAUX (FRANCE)

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Egis

On 16 March 2013, Bordeaux inaugurated a new bridge over the Garonne River: a vertical lift bridge in an urban setting that has already become a symbol in the city.

Why a vertical lift bridge?

The Bordeaux city area suffers from a lack of crossings over the Garonne: before the Chaban-Delmas bridge only five structures, one of which carries the railway, spanned the river.

To provide a better link between the two sides of the river – and especially between the Bacalan area on the left bank and Bastide area on the right, which are being revitalised – building a new crossing structure had become a matter of urgency.

But river traffic also had to be maintained, to allow cruise vessels and large sailing ships to access the city centre.

Preserving the port's usability was an issue of prime importance from historical, urban and functional perspectives. This is further borne out by the name of the site as it is inscribed on UNESCO's World Heritage list: "Bordeaux Port de la Lune". The Project Owner (Urban Community of Bordeaux, which has now become Bordeaux Métropole) accordingly decided that the river should be crossed by a bridge close to the water level, with a vertically lift span.

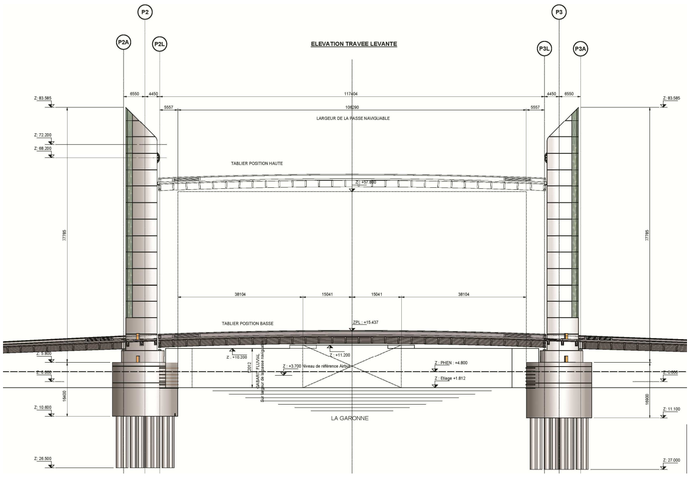
Jacques Chaban-Delmas Bridge, new entry to Bordeaux's Port de la Lune

Design

The design competition brief left the designer free to choose the number of sections and type of structures for the lift span and the fixed spans on either side of it.

The only set requirement was to propose a vertical lift bridge that would, naturally, be an architecturally coherent whole. But, no matter what choices the competitors made, the structure would, by its very nature, be complex.

Complex, first, because of the dimensions: with a width of 430 metres of the Garonne to be spanned, a navigable channel 106 metres wide and clearance of 57 metres to be provided, and with eight lanes used by pedestrians, cyclists, cars and public transport vehicles in dedicated lanes, the bridge is one of the largest movable bridges in the world.



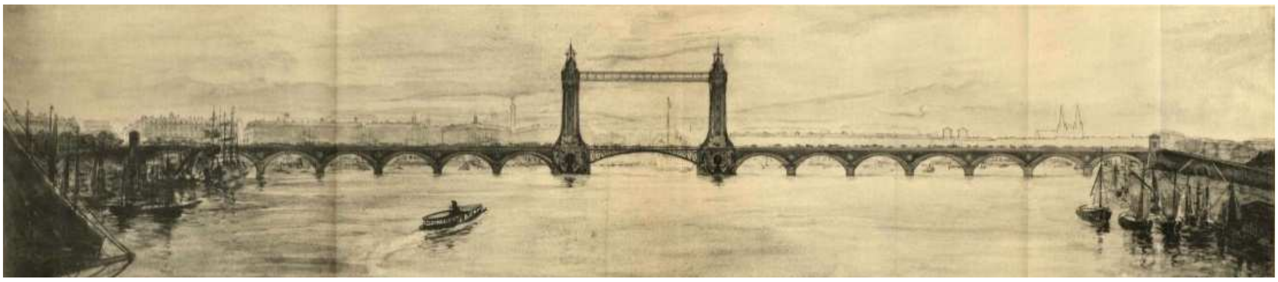
Exceptional dimensions for one of the world's largest mobile structures

Complex, second, because of the urban context: building a structure of this size in a city centre was a major architectural challenge.

Complex too because of the conditions of work in the Garonne river, an environment closer to a marine one than to a gently flowing water course: even though (along the river) the ocean is 100 km from the bridge, each tide reverses the direction of flow, creating strong currents and a very extensive tidal range (4 to 5 metres).

A guiding principle therefore dominated the technical design of the structure: simplicity, so as not to compound the difficulties outlined above.

The need for a single deck very quickly became evident to the design team, managed by EGIS-JMI (consultant for the client), working in association with the architect T.Lavigne, the expert consultant M.Virlogeux, and Hardesty & Hanover, the movable bridge specialist firm.



A vertical lift bridge over the Garonne in Bordeaux: a long-standing ambition! (archive photo, 1909)

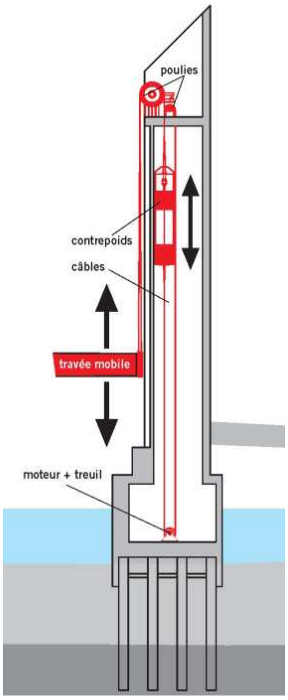
The quest for a light lifting structure naturally led EGIS-JMI's engineers to choose a box girder with an orthotropic slab for the lift span.

At the same time, Thomas Lavigne and the design team opted firmly for an urban amenity that would favour alternative means of transport, routing them along the outer sides of the bridge to separate them from road traffic.

The structure of the lift span embodies all of these choices: a 3.75 m high box girder with a 117 m span (span to depth ratio 1/32nd). The upper decking consists of a steel sheet with a minimum thickness of 16 mm, with V-shaped longitudinal stiffeners every 30 cm. The decking sheet is covered with an epoxy sealing and coating complex only 1 cm thick, developed specially for the project.

First lifting tests (December 2012)

Section of the lift span box girder during manufacture



This already light structure is balanced by four 600 tonne counterweights running in each of the four pylon towers. The counterweight boxes are connected permanently to the lift span by 4 x 10 suspension cables running around 4 m diameter sheaves. With this system, the lift span actually only weighs 100 tonnes!

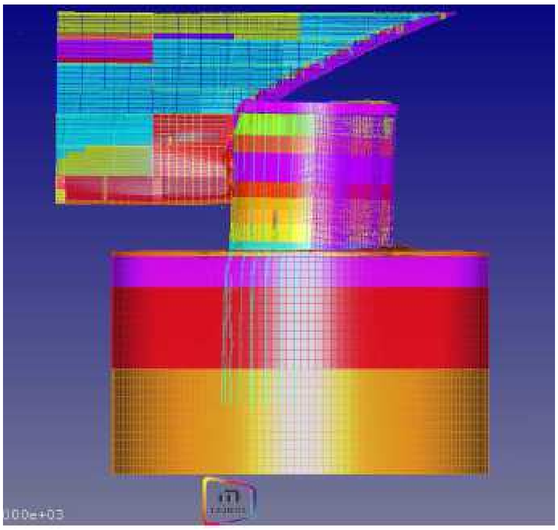
Movement of the counterweights (and therefore of the lift span connected to them) is obtained via a lineshaft common to each pair of pylons.

A low-power motor (132 kW) drives two drums, one under each counterweight. Two sets of operating ropes are wound around these drums and are connected to the bottom and top of the counterweights. Movement is thus fully controlled, as the counterweights can be both lowered (raising the lift span) and raised (bringing the span down).

The machinery (motors, shafts, brakes and drums) was tested by means of an in-factory mock assembly and full trials before shipping to the site. Once the machinery was installed in the foundation bases of each pair of pylons, on-site tests under load conditions were performed as background tasks, before arrival of the lift span.

Machinery spin test in shop

The monumental bases (44 m long, 18 m wide and 15 m high) are anchored to the bed of the Garonne on 20 piles with a diameter of 1,600 mm and length of around 20 metres.



The pylons are protected from direct impacts from vessels by four protective dolphins located upstream and downstream of the bases. These 18 m diameter, 15 m high cylinders are equipped with 22 lightly pre-stressed tie rods anchored in the substrate and able to be over-tensioned and thus restrain the dolphin in case of shock. Special dynamic calculations, including modelling of the bow of the design reference vessel, were developed for their detailed design

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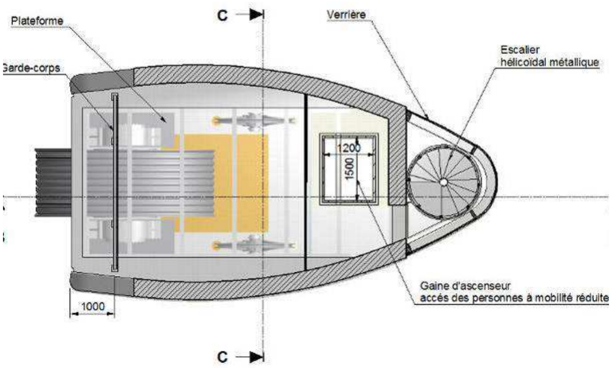


The 80 m high pylons have 40 cm thick walls. Their elliptical form, 5.30 m wide and 9.60 m long, houses the counterweights, lifting sheaves, elevators and maintenance stairs, in addition to fulfilling the pylons' prime function of supporting the guides for the mobile span during lifting.

The lightening of the structure described above, although essential for optimisation of the lifting plant, nonetheless has a down side: with an overall surface area of 5,000 m^2, and a height of 3.75 m exposed to the wind, coping with turbulent wind effects had to be considered from the earliest design stages.

On the basis of studies already conducted by Michel Virlogeux for the Millau viaduct, the profile of the edges of the box girder reduces the wind load. In addition, a judicious use of dissymmetry (the noses of the edges of the girder are offset upwards in relation to the centre-height of the box) gives the structure the form of an inverted aircraft wing. The deck therefore has a natural tendency to be pushed down onto its support by the airstream, the opposite of the lift effect used in aeronautics.

This firm stability was confirmed by special design calculations developed by EGIS-JMI. These took account of the wind turbulence on the site, on the basis of a series of measurements, and were confirmed by testing of a physical model in the CSTB wind tunnel in the city of Nantes.

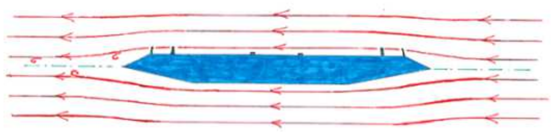
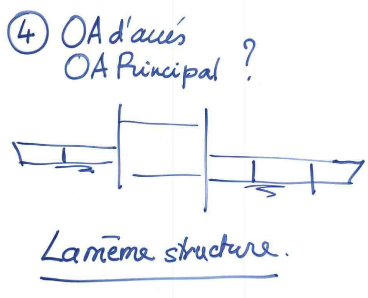
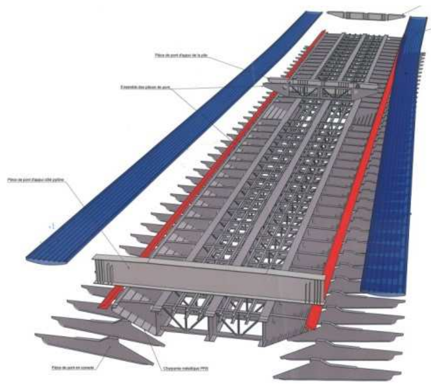


Illustration of air flow around the box girder, and verification on a physical model in a wind tunnel

Once the lift span was designed, design of the access spans was guided by the need for architectural continuity of the whole structure.





Choice of architectural continuity from the earliest sketches/bearing structure for access spans

The solution using composite, tri-beam decks with concrete road slab and bearing structure in metal "I" beams (in S460 steel because of the heavy tram/train loads) proved the most appropriate. The three "I" beams are stiffened crosswise every 4 m by diaphragms that extend beyond the side beams as outriggers supporting sidewalks.

Very different deck structures nonetheless blend into a single line

The intermediary pier of each access span is designed as a narrow ellipse, so as to be less visible under the structure and offer less resistance to the turbulent currents in the Garonne.

To reduce the heavy loads on the beams at the intermediary piers, the frame was laid temporarily on 30 cm thick supports; after concreting of the slab, the decks were jacked down to their final position. In this way, the slab was re-compressed, significantly improving the compounded behaviour of the whole structure.

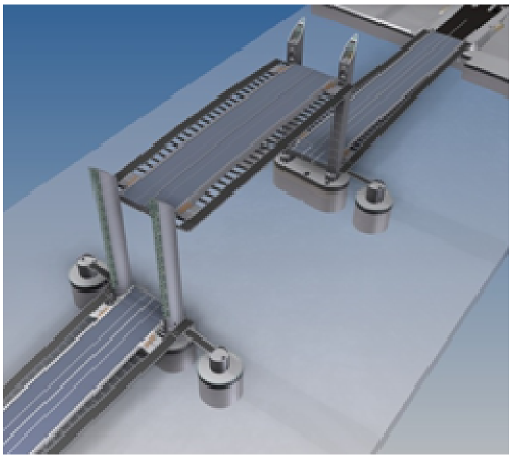
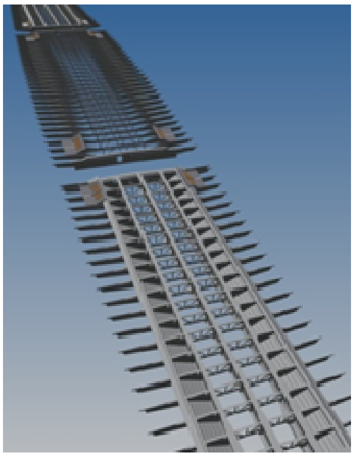
Laying of the right-bank access spans in August 2011

The joint work of the designers (engineers and architects) made it possible to overcome all of the difficulties and to provide complete design of the steel structures, civil engineering, foundations and mechanical plant from the inception stages of the project.

Ultimately, each beam section, each support, each transverse section of the bridge is unique, to allow for different parabola radii, variations in height, varying widths, etc.

Such a complex geometry required a full, 3D digital study of the structure and plant, conducted by EGIS-JMI. This ensured reliability of the multiple aspects of the design.

First, thanks to identification of potential conflicts in geometry for the very numerous different professional disciplines that have to interface to build a heavily equipped movable bridge: civil engineering, machinery, electricity and automatic control systems. It also confirmed the constructability of every part, on the basis of a simple principle: what's difficult to draw will be difficult to build!

Digital model of the overall structure and metal framework

The works: from prefabrication to installation, from fighting against to harnessing the tide

The design work upstream of the construction work was enriched by the experience of Vinci and Cimolaï, the companies in charge of civil engineering, construction and metal frames within the design and build consortium.


Work on the frames in the workshop: main box girder of the lift span and outriggers supporting the sidewalks

The Italian metal framework specialist had a major advantage: an assembly plant and loading wharf on the Adriatic Sea that made it possible to construct entire spans in the factory and convey them by sea and via the Gironde Estuary.

Leveraging its experience on the Rion-Antirion Bridge, in Greece, Vinci envisaged prefabrication of the pylon foundations and protective dolphins right from the start. This choice was confirmed when the Port of Bordeaux agreed to provide its dry dock (used to repair large vessels) just 5 km from the site.

Two series of transport operations were necessary to transport the cylindrical islands (2,500 tonnes) and the prefabricated bases (6,000 tonnes). Paradoxically, the bases were easier to convey, since their faired form made them comparable to the hull of a boat.

In the end, as many structures as possible were prefabricated, inducing a very large intrinsic gain in quality in relation to work on site, subject to hazards, notably weather conditions.


The concrete box girders during construction in the dry dock/Transport of an island under the Aquitaine Bridge

These methods also limited the inconvenience to river traffic, reduced the simultaneous activities on site of various fields on a tight schedule, and reduced environmental impacts in comparison with those that would have arisen from incessant terrestrial transports.

Assembly of the different parts was then eased by an unexpected player: the Garonne itself!

The construction teams overcame the unpredictable nature of the working environment by installing the prefabricated concrete box girders and bridge spans with the aid of the tides: brought to their supports by tugs or barges at high tide, the structures were lowered gently into place by the falling tide.

Here again, the method was envisaged at the design competition stage and guided design: for example, the relative position of the pylons and lift span was designed so that the 2,500 tonne metal section could literally slide between the massive concrete structures.

After a 6,000 km journey, a 2,500 tonne “package” that needed careful and precise handling!

In addition to demonstrating technical prowess, this operation also impressed the local inhabitants who turned out in large numbers to watch the operations placing the prefabricated mega-structures.

Since then, the Jacques Chaban-Delmas Bridge has been a success: the festivities and inauguration on 16 March 2013 took place in front of a record crowd.

It was cooperation between the engineers, architects and builders that made possible the design and then construction of this ground-breaking structure that remains remarkably close to the original drawings

Key figures

Overall length: 433 metres

Lift span: 118 metres long, 45 metres wide, 2,500 tonnes

Navigation channel: 106 metres wide, raising height of 47.60 metres

Operations: 120 per year on average

Raising time: 12 minutes

Pylons: 80 m high

Base: 44 metres long, 18 metres wide and 15 metres high

Protective dolphins: 18 metres in diameter, 10,000 tonnes

Cost of the project: €160 million (including taxes)

Participants

Design consortium:

EGIS-JMI (Consultant - Structures) / Architecture and Structure (Architecture) / Hardesty & Hanover (Mechanisms–Electricity) / M.Virlogeux (expert consultant)

Construction consortium:

Vinci Construction GTM Sud-Ouest (Consultant and Civil Engineering) / Cimolaï (metal framework) / NFM (mechanisms)

Owner:

Bordeaux Métropole (formerly Communauté Urbaine de Bordeaux)