



THE YAVUZ SULTAN SELIM BRIDGE

Special Issue – November 2016

STRUCTURE

Magazine Special issue

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FREYSSINET

THE IMAGE

Between April 2015, when the first stay cable was installed, and February 2016, when the last one was installed, up to 200 people, including about 60 supervisors, worked simultaneously on the towers which reach a height of more than 300 metres, the deck, which runs 75 metres above the waters of the Bosphorus and on dry land in the offices overlooking the worksite.



The word

I remember vividly my visit to Normandy Bridge as a young engineer in 1992. The 856 metre span beat the previous world record for a cable stayed bridge by more than 250 meters.

At the time, some technical journals began to question the wisdom of such a leap in technology. But pushing the boundaries is what challenges engineers, and the success comes from understanding and managing the risks. It is important as engineers that we can be audacious in our aspirations.

In 2012, 20 years later, Freyssinet set a new world record with the Russky Island Bridge and its 1,104 metre cable-stayed span, which would have seemed folly back then. And now, in 2016, comes the Yavuz Sultan Selim Bridge in Istanbul, Turkey. Designed by Jean-Francois Klein and Michel Virlogeux with its 1,408m span, a hybrid solution of suspension and cable stays, this bridge takes another leap forward. The challenges were many, but the realisation of this bridge is a testament to the designers and their vision, and not least to our men and women on the project site who worked with fortitude, passion and humour. I wish to thank ICTAS and ASTALDI for the confidence they placed in us. We are proud to have shared in this outstanding experience with them. The Yavuz Sultan Selim Bridge is an iconic engineering structure which will help to inspire us all. I hope you enjoy this pictorial record of an extraordinary bridge and like me, you look forward to our next landmark structure. We already have some ideas...



PATRICK NAGLE
CHIEF EXECUTIVE OFFICER
OF FREYSSINET

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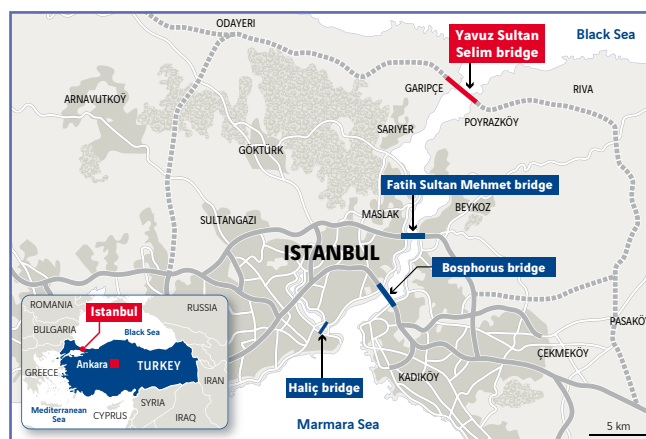
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Key figures

- 1,408 metre span
- 176 stay cables
- 597 metre length of longest cable
- 7,800 tonnes of steel for the stay cables

The project



The City of Istanbul, linking Europe and Asia, has undergone unsurpassed growth over the past several years. The many projects developed to accommodate it include the Northern Marmara Highway, a 150-kilometre motorway that bypasses Istanbul to relieve traffic in the city centre. The project culminates in the Yavuz Sultan Selim Bridge, a 2,164-metre structure spanning the Bosphorus north of the city near the Black Sea.



Design



The design of the third Bosphorus bridge was awarded in early 2012 to Michel Virlogeux⁽¹⁾ and Jean-François Klein⁽²⁾. In just nine weeks they drew up the concept of the structure that became the Yavuz Sultan Selim Bridge in 2016. From the start, a variety of techniques were devised for the crossing, which has a 1,408-metre span and carries a dual four-lane motorway and two railway tracks. The design ultimately selected was a hybrid cable-stayed suspension bridge, a technique previously applied on the Brooklyn Bridge in New York that overcomes a number of challenges related to size. The bridge completed four years after the start of design studies is consistent with the first drawings, give or take a few details. It constitutes a technical feat.

(1) Michel Virlogeux has been an independent consulting engineer since 1995. He is known for designing over 100 structures worldwide, the most famous of which are the Normandie Bridge and the Millau Viaduct in France and the Vasco de Gama Bridge in Portugal.

(2) The T Ingénierie firm specialises in designing complex structures and handles design studies, works and site supervision. It is based in Geneva, Switzerland, and managed by a Board that includes Jean-François Klein.

Partners

KGM, the project owner

The General Directorate of Highways (KGM) is a state agency in charge of the construction and maintenance of all public roadways outside of cities and towns in Turkey. It was established on March 1, 1950 following the acceptance of the International Highways Act in 1949. The agency is a sub unit of the Ministry of Transport and Communication.

ICA, the general contractor

ICA was established as a partnership between IC İnşaat Construction, the locomotive company of IC İbrahim Çeçen Investment Holding A.Ş. that has signed its name to many international achievements, and Astaldi, again another internationally renowned and successful construction company. Besides the Yavuz Sultan Selim Bridge, ICA has also undertaken the expansion project for the Pulkovo Airport in St. Petersburg and the Western High Speed Diameter (WHSD) project in Russia.

ICTAS

Since the first day of its establishment up to the present, IC İnşaat Construction has signed its name

to many successful projects, among them airport construction projects, harbor construction projects, marina construction projects, high-speed train projects, highway and bridge construction, high-capacity power plants, smart buildings, business centers, tourism facilities, irrigation system construction projects, government buildings, mass housing, hospitals, university and school construction projects.

ASTALDI

The ASTALDI GROUP is one of the most important firms in the field of large-scale works. An international player for more than 90 years, it addresses the market by developing complex and integrated initiatives (design, construction, operation), with solid expertise and highly specialised human resources. Projects carried out are often the results of successful collaborations with world's most famous "starchitects". The Group's segments of activity range from Transport Infrastructure to Hydroelectric and Power Plants, from Civil and Industrial Construction to Systems and Facility Management, as well as Management of Complex Systems.

PORTFOLIO

176 Freyssinet stay cables
were installed on the Yavuz
Sultan Selim Bridge.

06

07



November 2014.
The project is proceeding apace.
Soon the Freyssinet teams will be
able to install the first cables.

08

09



April 2015. The first cables are tensioned. One month later, 10 of the 176 stay cables have been successfully installed.

10
11



View from one of the two towers, at a height of 322 metres. The first cables have been installed.



The cables are made up of between 65 and 151 strands with a tensile strength of 1,960 MPa to support the weight of the deck and the traffic on the bridge.

Key figures

- 2,164 metre** length

1,408 metre span

176 stay cables

597 metre length of longest cable

7,800 tonnes of steel for the stay cables

Anchor units, **75 to 151**

Maximum height of dampers: **7.2 metres** above the deck

2 suspension cables, each **2,420 metres** long

34 pairs of vertical hangers
- 2 towers with a height of **322 metres**

57 segments

58.50 metre deck width

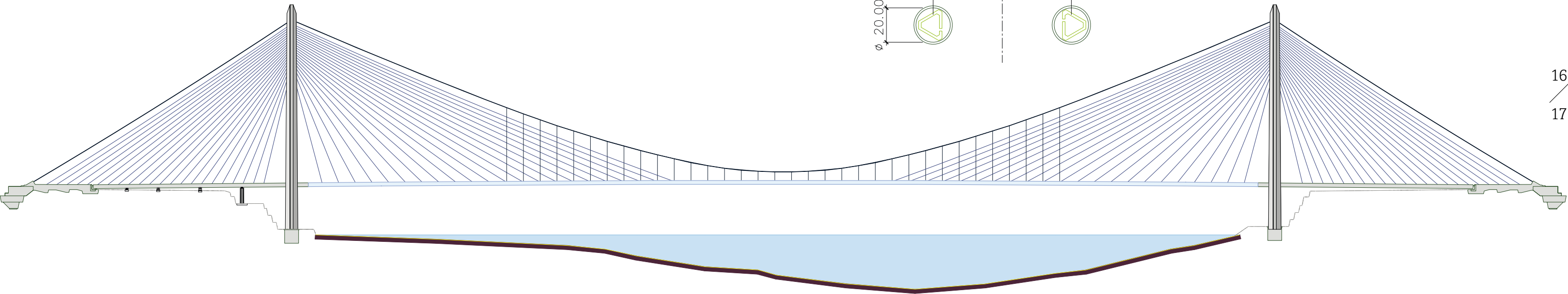
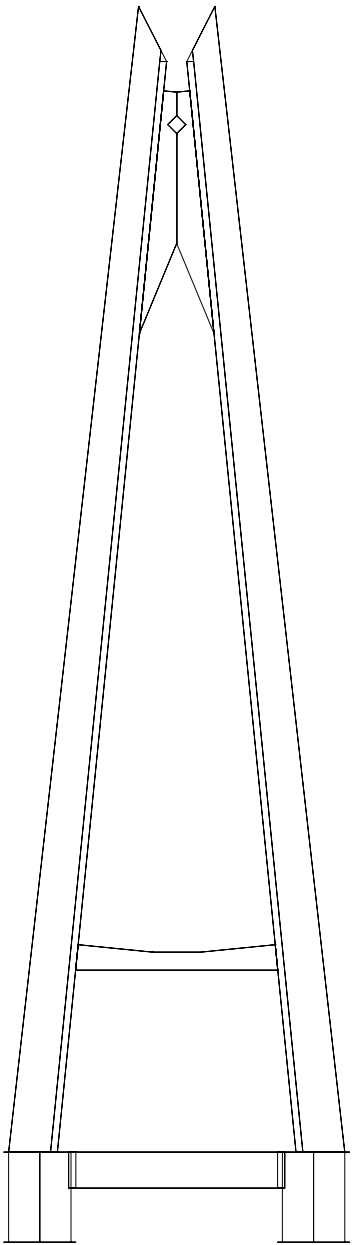
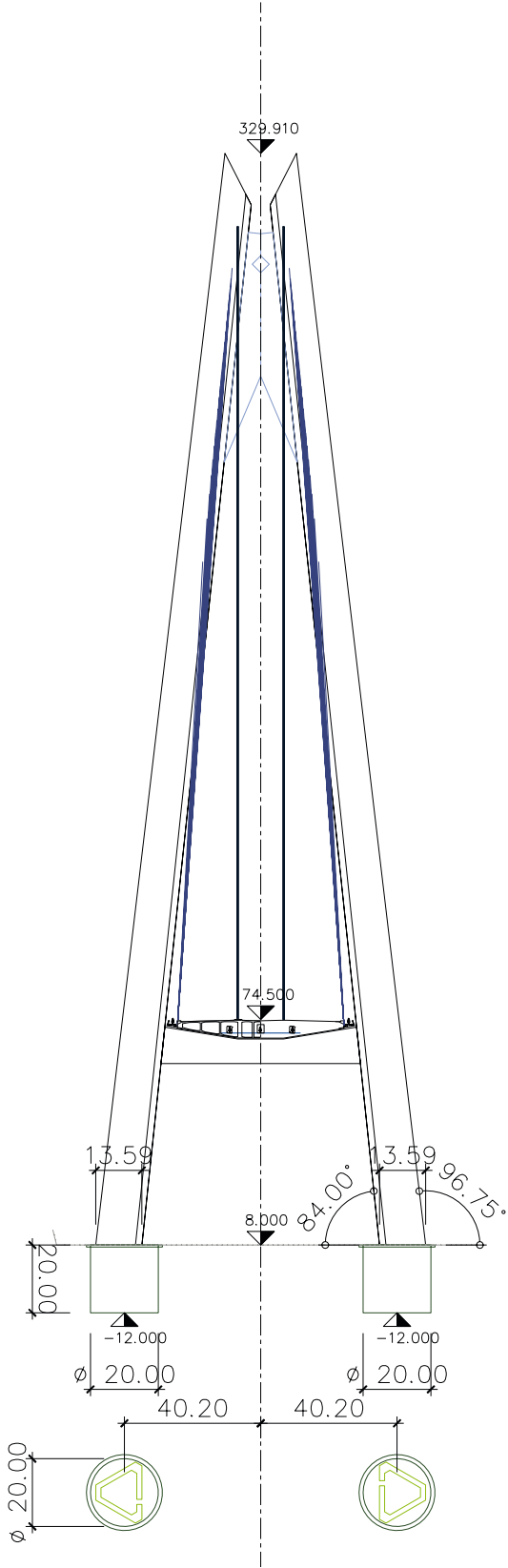
Cable stay tensile strength: **1960 MPa**

2x4 motorway lanes

2 railway tracks

4 years of work from initial drawings to handover

Up to **200 Freyssinet employees** working simultaneously



Members of the Freyssinet / Freysaş team working on the bridge.



Hebetec lifted 17 segments weighing 1,000 tonnes each at a speed of 10 m/h.





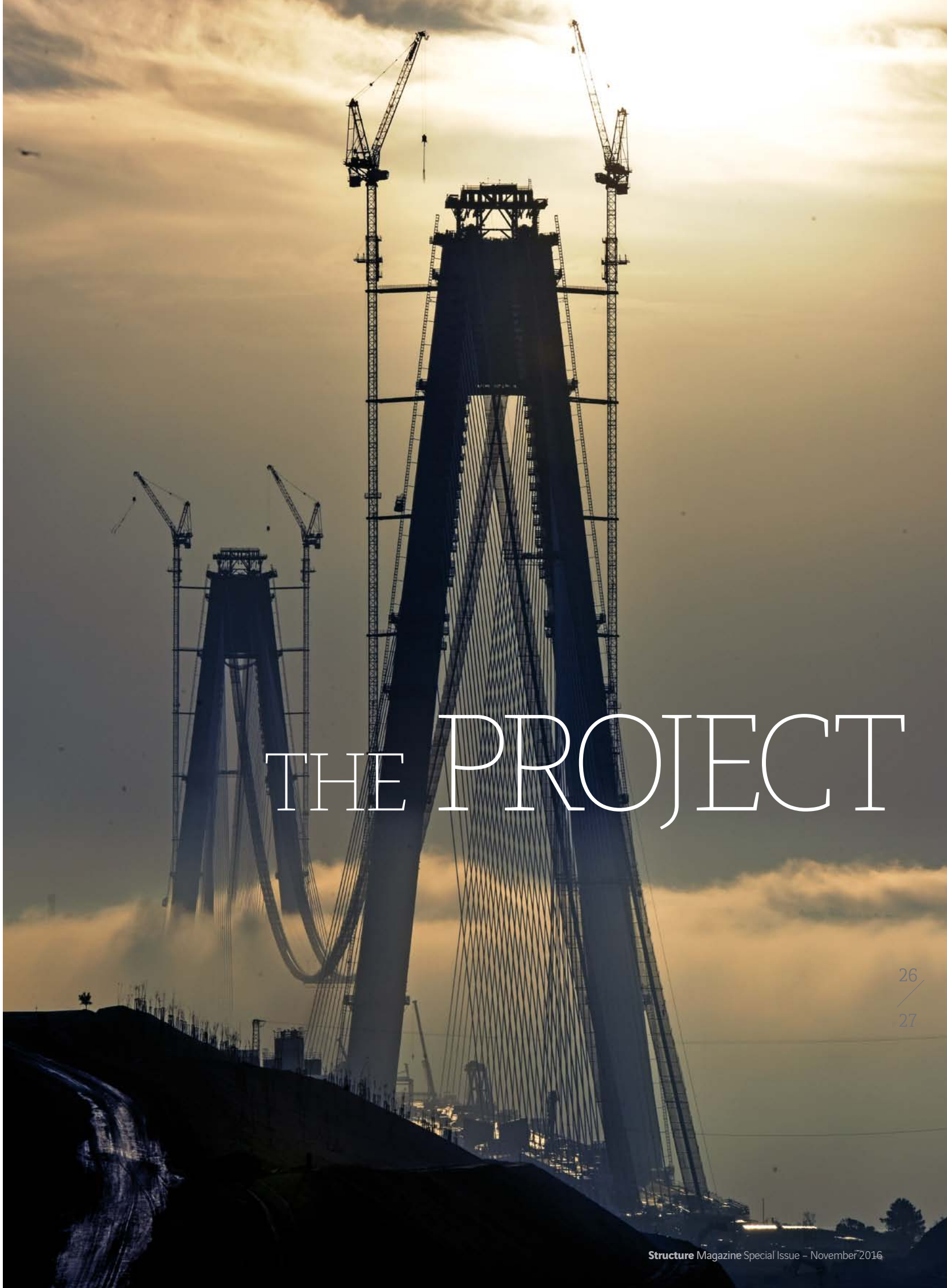
The project is nearing completion. Only a few segments remain to be installed.



26 August 2016. Four years after the start of the project, the Yavuz Sultan Selim Bridge is inaugurated.



Nearly 200 Freyssinet employees were involved in the project – a great human undertaking.



THE PROJECT

The project

YAVUZ SULTAN SELIM BRIDGE

THE RECORD-SETTING

➤ The essentials

- **The project** Supply and installation of the 176 cables and dampers of the Yavuz Sultan Selim Bridge in Turkey.
- **Structure** The hybrid (cable-stayed suspension) Yavuz Sultan Selim Bridge has total length of 2,164 metres. Its towers are 322 metres high and its span is 1,408 metres long. It has set a new world record for a composite road-rail bridge and for stay cable length.
- **Duration** 2012 to 2016. Cable installation began in April 2015 and ended in February 2016.

ISTANBUL — TURKEY

It took only four years to build the majestic Yavuz Sultan Selim Bridge spanning the Bosphorus in Istanbul. The Freyssinet teams responsible for the cable-stayed part of the structure installed its 176 stay cables over a period of 10 months. The major project will remain an indelible memory for all those who worked on it.

The hybrid (cable-stayed suspension) Yavuz Sultan Selim Bridge spanning the Bosphorus north of Istanbul, designed by Jean-François Klein (T-Ingénierie) and Michel Virlogeux, has a total length of 2,164 metres. The bridge's innovative hybrid design sets a number of records : the highest towers (322 metres), the widest deck (59 metres), the longest span for a composite road-rail bridge (1,408 metres) ; and of course the longest stay cables (597 metres) exceeding the length of those of the Russky Island Bridge in Vladivostok, Russia with a 1,104 central span, which is also equipped with Freyssinet stay cables. With its eight motorway lanes (four on each side) and ultimately its two railway tracks, the Yavuz Sultan Selim Bridge will facilitate traffic between Europe and Asia. Freyssinet was in charge of the studies, design, supply and installation of the stay cables and dampers for this record-setting structure. The company also supplied and installed 1,500 tonnes of prestressing and raised the 17 segments of the bridge's central span.

A technical...

The cable technical design studies got under way at Freyssinet at the end of 2012. The teams in charge of the project faced a substantial number of challenges due to the specific features of the structure (see page 30). The cables had between 60 and 151 strands with the standard 1860 MPa tensile strength used in cable-stayed bridges to support the weight of the deck and traffic. A new 151-strand anchor was designed and several innovative damper solutions were developed, as were special deviators.

...and human challenge

On 3 April 2015, less than two years after the cornerstone was laid, the Freyssinet teams installed the first cable of the back span on the European side tower. It was 154 metres long and had 99 strands. Just over 10 days later the first cable was installed on the Asian-side tower. The cables were installed in parallel on both sides of the Bosphorus throughout the project. As soon as the second cable was installed, resources were made available to work on cable installation day and night, seven days a week on both sides of the Bosphorus. The project reached its standard pace of ten days per cycle during the next cycle*. The first 160 stay cables were installed within seven and a half months. Following a two-month interruption to make way for the installation of the first central segments, the last 16 stay cables were installed in just over a month.

On 22 and 23 February, the world's longest stay cables were attached to the European and Asian side towers.

A total of 7,800 tonnes of steel were installed in less than nine months of works, an average of 900 per month. To maintain this pace, Freyssinet called on specialists from all its subsidiaries. Up to 200 people, including about 60 supervisors, worked simultaneously on the structure's two towers, which rise more than 300 metres; the deck, which stands 75 metres above the water of the Bosphorus; and on land in the offices overlooking the worksite.

The finishing work, although not as spectacular, was a similar challenge for the teams. It involved coordinating more than 12 different activities taking place throughout the immense structure and the installation of the 172 damper masts – metal structures with a length of over seven metres, which weigh more than five tonnes and were adjusted with millimetre precision by means of a resourceful support technique.

* A cycle includes the following operations:
- lifting and installation of a metal segment in the central span,
- installation of a pair of stay cables in the back span and a pair of stay cables in the opposite span.



The partners

- **Client**
KGM (Turkish Ministry of Transport)
- **Concessionaire**
ICA (JV İçtaş and Astaldi)
- **Design**
Jean-François Klein – T-Ingénierie & Michel Virlogeux
- **Construction**
Hyundai Engineering & Construction / SK Engineering & Construction

DAMIEN DELBOS, PROJECT MANAGER

“In choosing to build the majestic outsized bridge at the entrance to the Bosphorus, Turkey gave us an opportunity to exceed everything that had been done before, and we welcomed it!”



Lifting the spans

➤ Hebetec was in charge of lifting the 17 central span segments. To do this, the Hebetec teams worked with Freyssinet to devise and type approve the best way to lift the 1,000 tonne segments. It was ultimately decided to use the main cable to support the complex operation. It took four months to produce the equipment and two months to install it. Each segment was lifted at a speed of 10 m/h. The bridge was keyed in March 2016.

Hebetec offers comprehensive services in the lifting engineering area. The field of activities ranges from the preparation of solution concepts and the execution of lifting, lowering and sliding heavy loads up to renting out hydraulic devices, which, to a large extent, are developed by the company.



Access viaducts

➤ In parallel with the work carried out by Freyssinet on the Yavuz Sultan Selim Bridge, the teams from Freysaş, Freyssinet's subsidiary in Turkey, were in charge of designing and building the three highest access viaducts and for prestressing the bridge.

Freysaş was founded in 1988 as a company jointly held by Freyssinet and the Turkish Yapı Merkezi group. Since its inception, Freysaş has taken part in more than 300 projects in more than 12 countries. The company delivers the full range of Freyssinet solutions and services. Its recent project include the upgrade to seismic standards of the Marmara hospital and the Haliç bridge in Istanbul.

A technical challenge on an unprecedented scale

Following an invitation to tender for the cable-stayed part of the bridge in October 2012, Freyssinet engineers immediately set to work to meet the technical challenge and design the most suitable cable system for the structure.

The deck was to be longer, wider and more flexible than the deck of the Russky Island bridge in Vladivostok, which held all the records at the time. Innovative, never before seen solutions were therefore called for. A team from the Freyssinet Technical Department worked full time on the project.

Chief Engineer Matthieu Guesdon, who coordinated the technical team, remembers that *«We thought about it at night, on the weekend – we were operating full steam ahead.»*

The cables had between 75 and 151 anchor units with 1960 MPa tensile strength to support the weight of the bridge and traffic. A new 151-strand anchor system was specially designed. The team also developed a patented solution for the stay cables numbered 11 to 22: cardan joint dampers (see insert).

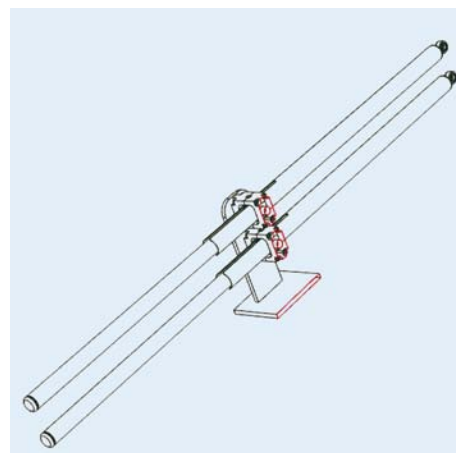
«When we were uncertain, we often repeated the old saying, «There are no problems, there are only solutions,» said Matthieu Guesdon. By the end of 2015, the design studies were being finalised and the testing phase was proceeding at full speed.

«We carried out tests on an unprecedented scale, commensurate with the size of the structure,» says Matthieu Guesdon. Everything from deviators to anchorage systems, and strand sheath wear was painstakingly investigated.

A first cable, with a length of 154 metres, was installed in April 2015 and the team from the Technical Department remained on standby throughout the works. *«Even now that the bridge has been inaugurated, the project is still with us,» says Matthieu Guesdon. «We were very fortunate to have been part of it, to have been familiar with the technical details and to have played a role in a project on this scale. The bridge is, you could almost say, a member of the family.»*



The cardan joint damper concept is based on the use of special hydraulic pistons. One of each piston's connections is not mounted on the end but rather in the middle of the body with an articulated connecting piece that moves in both directions. This system limits the span of the support masts and reduced the amount of steel required to produce them.



The year

1977

The Brotonne Bridge

The Brotonne Bridge, Freyssinet's first cable-stayed bridge, was opened to traffic in Normandy, France.

The 1,278 metre long structure with a 320 metre span, designed by French engineers Jean Muller, Jacques Mathivat and Jacques Combault, held the length record for a cable-stayed span at the time it was built.

Around the world...

Concorde

On 22 November, at 8:47 a.m., two Concorde airplanes, one from Heathrow in the U.K. and one from Roissy in France, landed at JFK in New York. The event marked the start of regular supersonic flights between Europe and the U.S.

Star wars

On 25 May, the first instalment of the Star Wars trilogy by American filmmaker Georges Lucas opened in 32 theatres in the United States. *Star Wars* won six Oscars.

