An elegant hybrid solution to cross the Bosphorus strait with a mixed-traffic bridge, in an ever-expanding urban context

ASTALDI

POLITECNICO MILANO 1863

17 ottobre 2017

Istanbul and the Bosphorus

A capital city developed on the sides of two continents - Europe and Asia.

In a unique geographical condition.

This condition has affected the urban growth and development process of the city, as well as that of the entire network of transportation systems.

In 2014: population of about 14 million inhabitants (perhaps 17 ?).

More than half residing in Asia but whose working activities - for a good 90% of them - are based in Europe.

Satellite image of the Bosphorus strait

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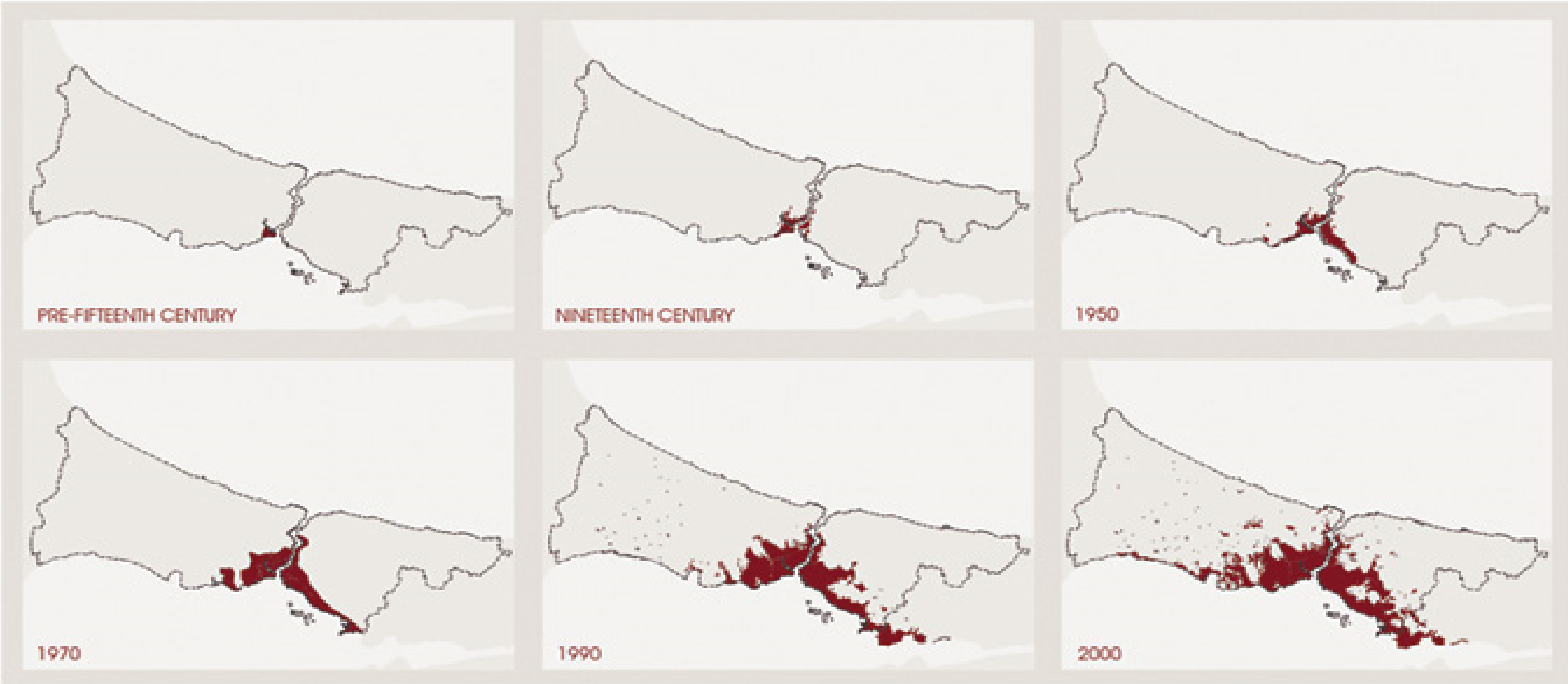
DIACHRONIC DEVELOPMENT OF İSTANBUL



GROUTH OF POPULATION

year inhabitants

- 1945 860.000
- 1960 1.466.000
- 1970 2.132.000
- **1980 2.773.000**
- **1990 6.629.000** +139%
- 2000 8.803.000
- 2010 13.120.000 +50%

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Istanbul is renowned for its massive traffic

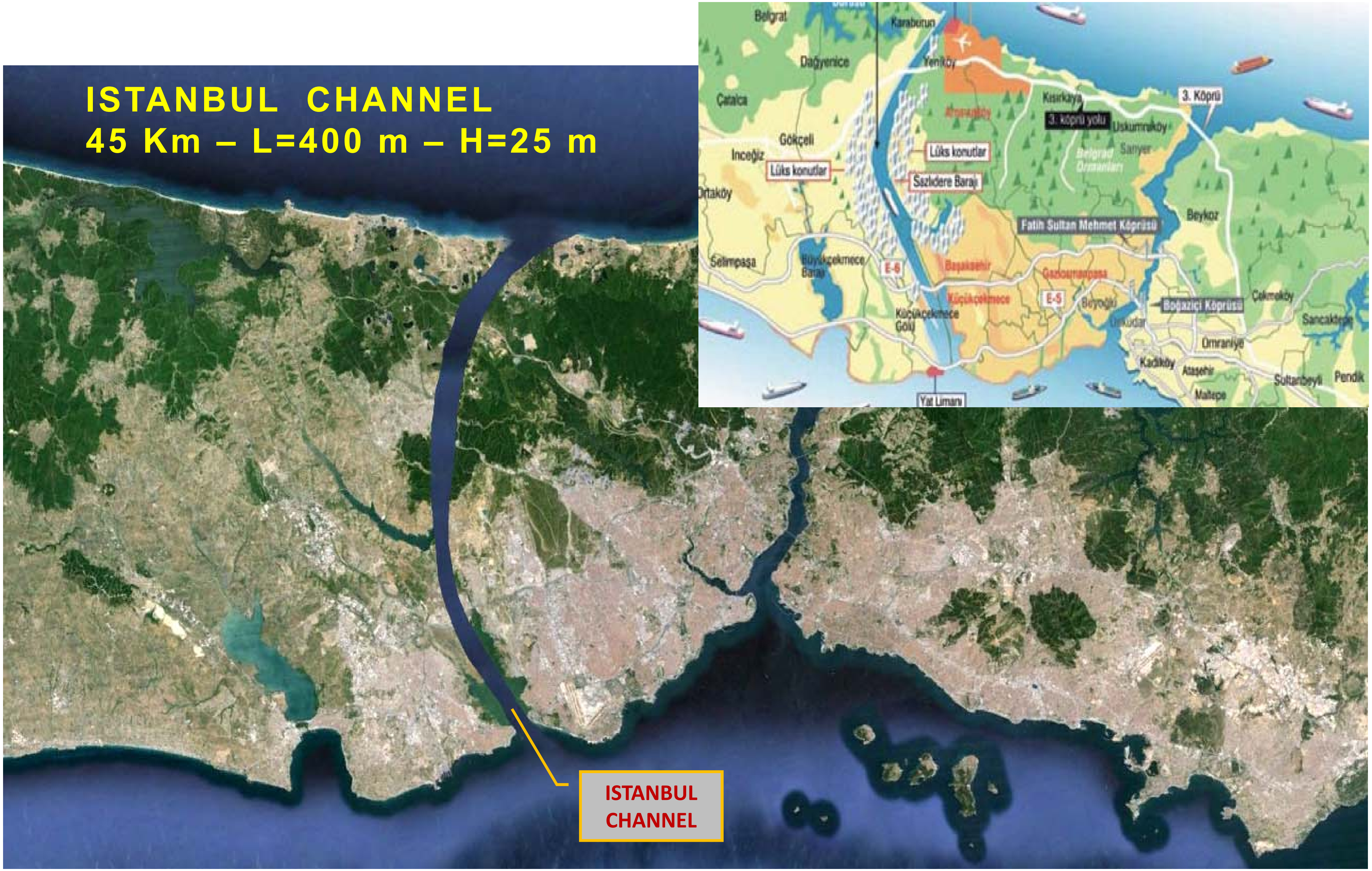
In 2015 Congestion Index - a calculation time waste due to traffic delays - showed that Istanbul ranked first averaging 58% - with a peak of 109% during evening hours.

That means that the time wasted doubles the driving time required.

THE CROSSING RUN BEGAN ON THE 70th

1° BOSPHORUS BRIDGE	1074 m - SUSP. ROAD BRIDGE	2x3 lane	1973
2° BOSPHORUS BRIDGE	1090 m - SUSP. ROAD BRIDGE	2x4 lane	1988
MARMARAI – RAILWAY TUNNEL	14000 m - ROAD TUNNEL	2x1 lane	2013
EURASIA – TUNNEL	5400 m - ROAD TUNNEL DOUBLE DECK	2x2 lane	2016
3° BOSPHORUS BRIDGE	1410 m - MIXED SUSP. BRIDGE	2x4 lane+RAIL	2016
ROAD TUNNEL - PLANNED	TBD		

ISTANBUL CAN BECOME AN ISLAND ?



BOSPHORUS – THE ORIGIN MIXED WITH LEGEND

The **Bosphorus the south border between Europe and Asia.**

Length 37 km
Width 550m – 3.000 m
Depth 30 – 120 m

The name means the «crossing» of the «heifer», from the GreeK «Βοῦς» ("bous", cow) and πόρος, ("poros", crossing).

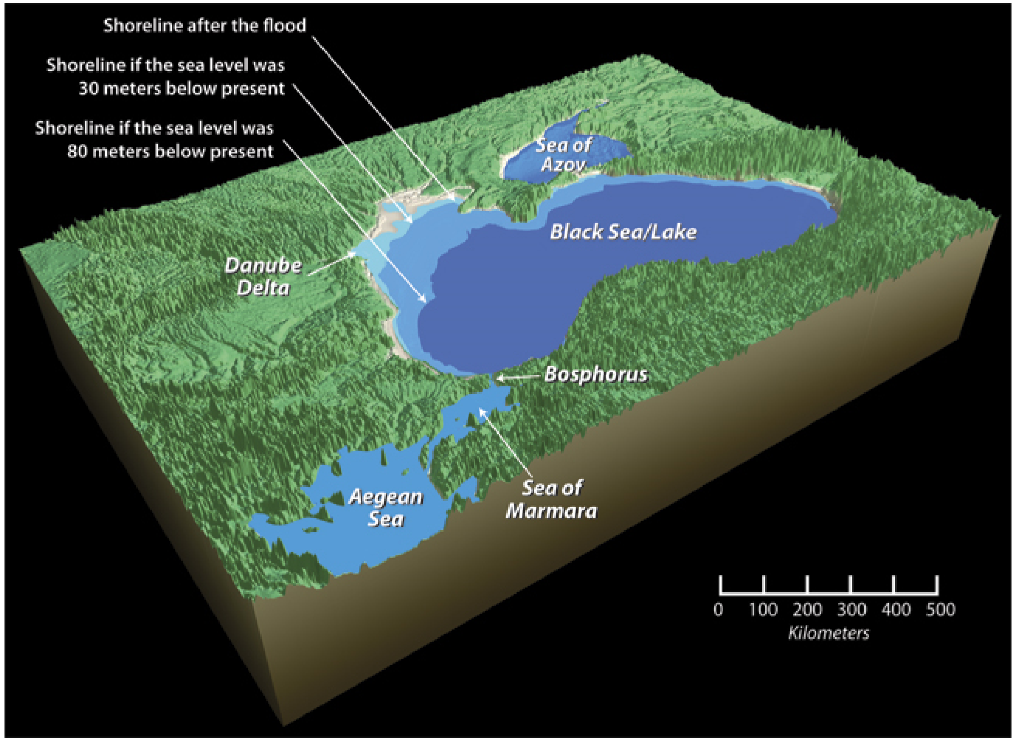
It comes from the myth that “I”, a girl beloved by Zeus, has since been transformed into a heifer then pursued by a taffeta sent by the jealous Era.

Withered up to madness, I walk across Greece to cross the strait that separates her from Asia.

The Bosphorus: HOW ?

BOSPHORUS – THE ORIGIN MIXED WITH LEGEND

Hypotheses Ryan – Pitman (1998)



The **Black Sea deluge** is a hypothesized catastrophic rise in the level of the Black Sea approx. 5.600 BC from waters from the Mediterranean Sea breaching a sill in the Bosphorus strait.

10.000 cubic miles (42 Km³) of water every day (200 times Niagara falls), for 300 days, Increasing the level 15 cm every day.

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Two bridges already exist across the Bosporus, linking Europe to Asia.

The design of which has been selected and is famous for their elegance.

Severn suspension bridge (UK)

The first bridge which inspired the others was the Severn suspension bridge, central span length 988 m.

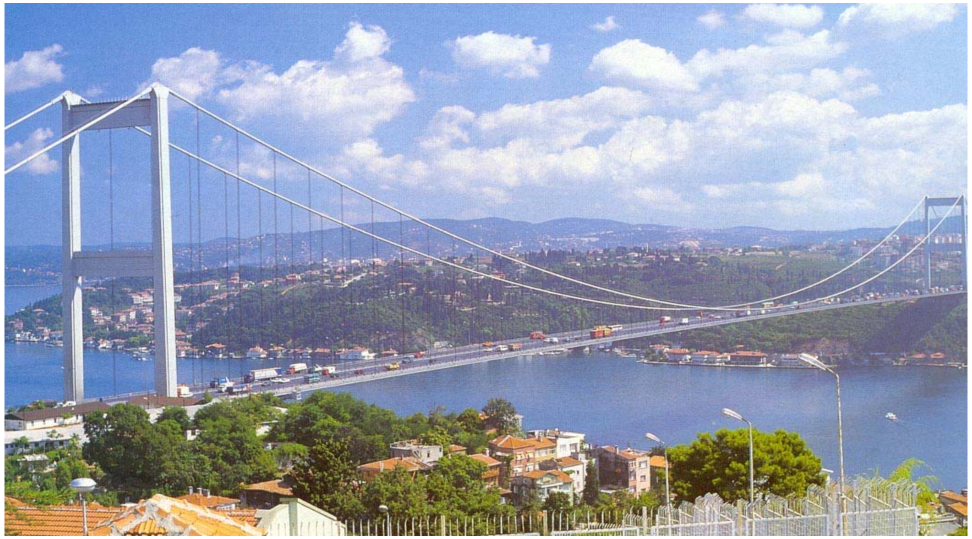
Opened in U.K. in 1966, it has been a revolution in the design of suspension bridges, with a streamlined orthotropic box girder for the deck and inclined hangers.

1st Bosphorus Bridge

Built in 1973, has been directly inspired from the Severn suspension bridge, with an orthotropic box girder and inclined hangers (actually modified with vertical one)

2x3 lanes of 3,50 m
Main span 1.074 m
Deck width of 33,40 m

2nd Bosphorus Bridge



Built in 1988, re-used the same concept with a similar suspension system, but with vertical hangers.

2x4 lanes of 3,50 m
Main span length 1.090 m
Deck width of 39,00 m

The **Turkish Authorities KGM** decided to build a new motorway 2x4 lanes, by-passing Istanbul in the north near he Black sea, a sort of ring in order to prevent transit to heavy vehicles in the existing two Boshorus bridges.

The name is “Northern Marmara Motorway”, including a new bridge crossing the Bosphorus, that in addition to road vehicles it provides **a double track railway.**

MTW 96 Km
n.20 INTERC.

CONNECT. & RAMPS
94 Km

60 VIADUCTS
4 TUNNELS

1) Odayeri-Paşaköy Section 60 Km

2) Mahmutbey-Odayeri Section 22 Km

3) Çamlık-Reşadiye Section 13 Km

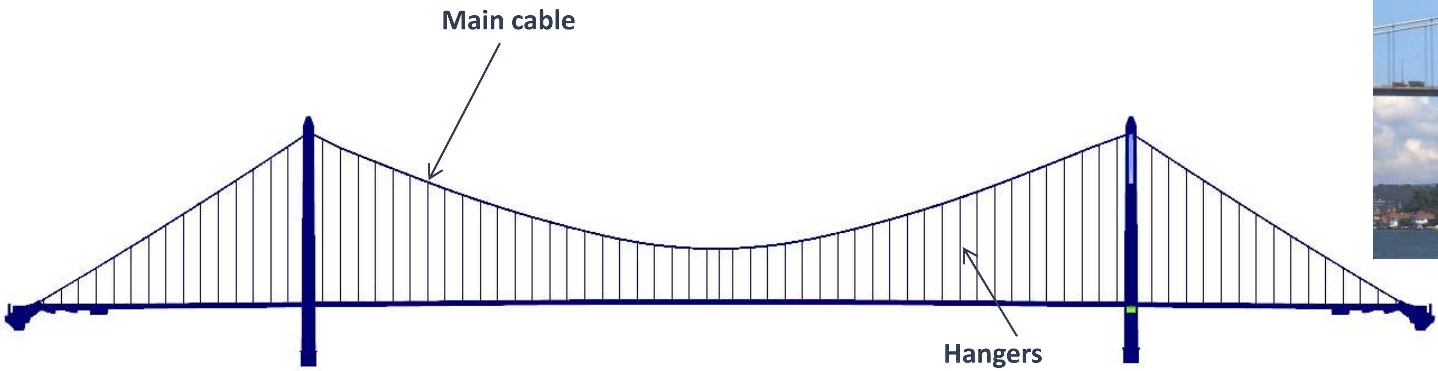
The requirements for this structure insisted on the architectural quality of the design to be developed, underlying a familiarity with the lines and shapes of the two previous suspension bridges across the strait.

But all existing long span bimodal bridges (road + railway) are designed with a two level deck, usually with the railways passing below the roadways.

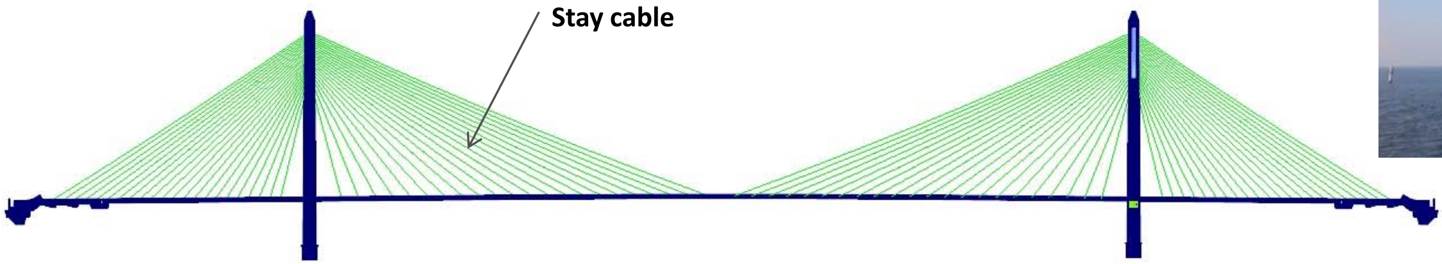
Such designs, like for the Bisan Seto bridges in Japan, opened in 1988, are double-deck bridges and are generally heavy structures.
This type of bridges have not the elegance of the streamlined box girders of the modern long span roadway suspension bridges built after the pioneer Severn and Bosporus bridges.

LONG SPAN BRIDGES

Suspended bridges



Stay cable bridges



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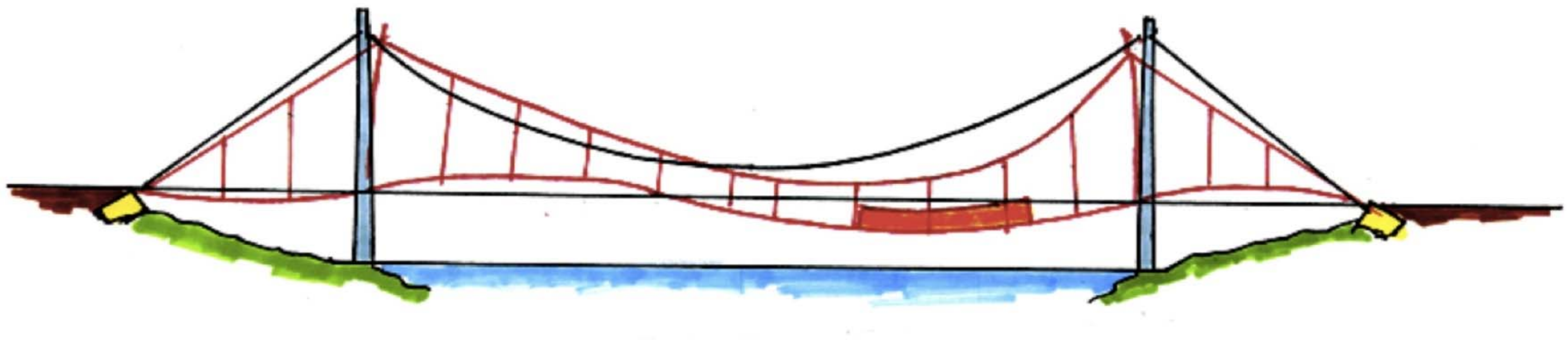
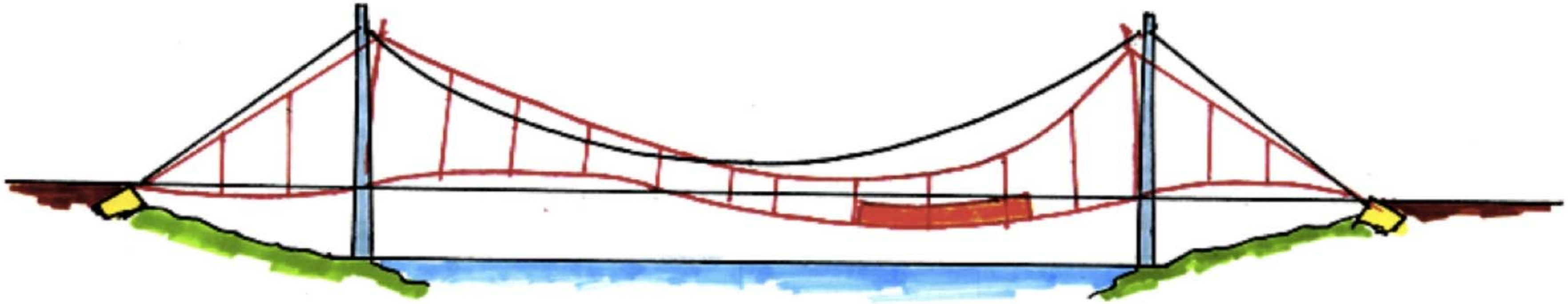
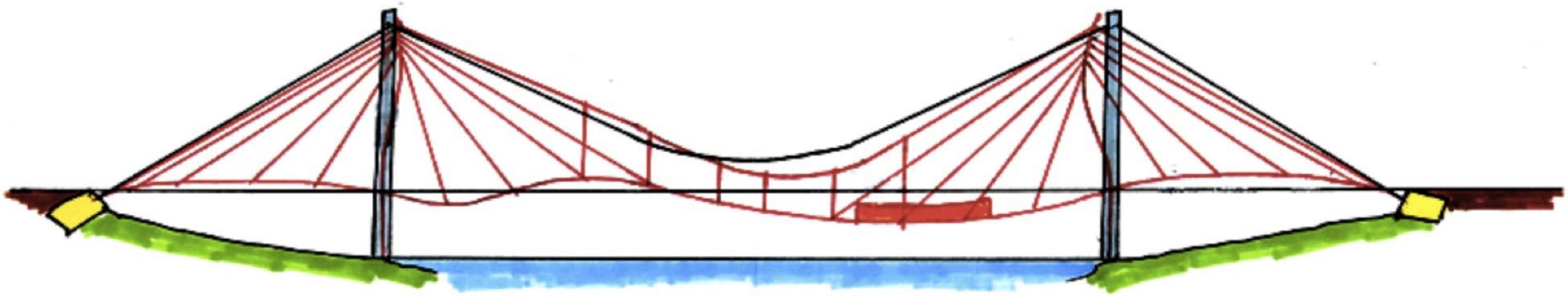


But a classical suspension bridge with a rather flexible deck is not easy to adapt to the heavy and concentrated train loads.

When the train is at about quarter span, the suspension cables move down under the load and up on the opposite side, with a limited efficiency producing very large deflections.





This is why it has been decided for the 3rd Bosphorus Bridge to add stay cables, called stiffening cables, close to the towers.

So the heavy and concentrated loads at quarter span are directly driven to the corresponding tower, reducing deflections by a factor which can reach 3 or 4.

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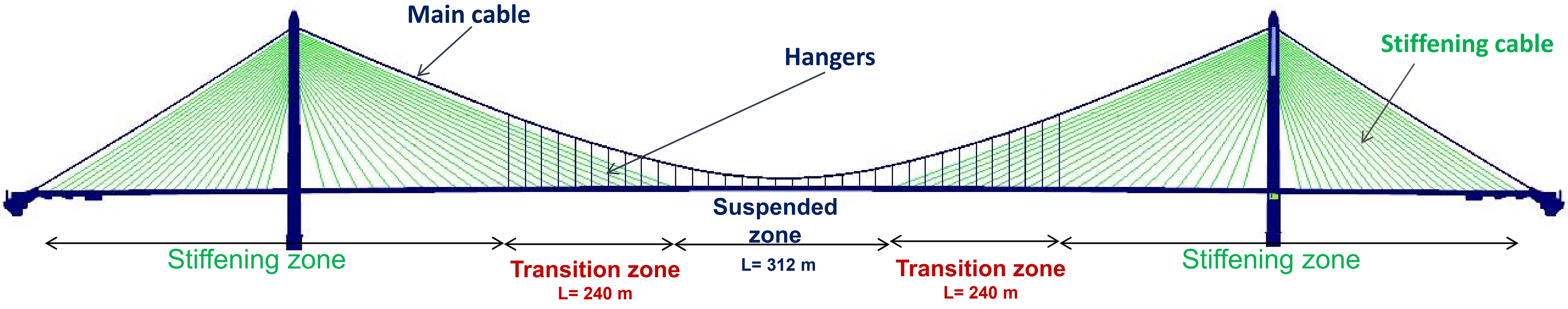
A HYBRID SOLUTION FOR THE 3rd BOSPHORUS

H.R.S.B. High Rigid Suspension Bridge

Conception: **Michel VIRLOGEUX**

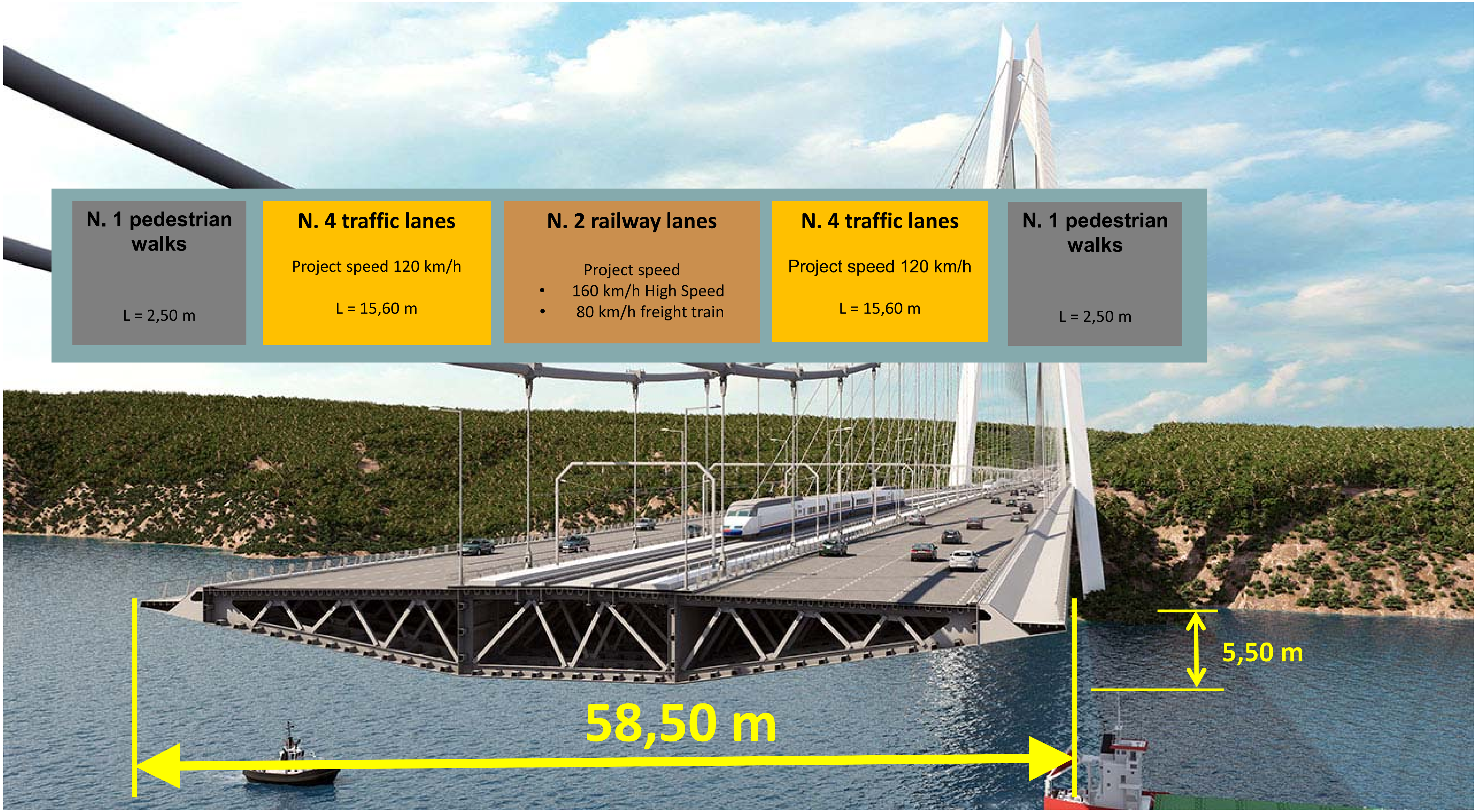
Designer: **Jean François KLEIN**
Vincent DE VILLE



THE BRIDGE TOWERS ARE "A" SHAPED THIS GEOMETRY PROVIDES ENHANCED STABILITY

LONG SPAN BRIDGES

LONG SPAN BRIDGES



THE BRIDGE HAS A STREAMLINED ORTHOTROPIC DECK WHICH IMPROVES THE AEORODYNAMICS

LONG SPAN BRIDGES

CLASSIC (m)	COMPARISON DECK DISPLACEMENT	H.R.S.B. (m)
- 9,00	Vertical displacement at the center under max. loads	- 4,75
7,00	Transversal displac. under extreme wind loads at the center	1,65
0,70–1,00	Horizontal longitudinal displac. under live loads at the tower	0,53
0,06	Longitudinal displac. under train braking loads at the tower	0,038
7,00	Transversal displacement under earthquake (50 years)	1,54

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A MIXED or HYBRID SOLUTION

EXISTING BRIDGES


Niagara Railway Suspension Bridge 1870 J. Roebling

Tamar Bridge, UK (1961)
Strengthened by adding stay cables (1999)


Brooklyn suspension bridge 1896 J. Roebling

Wujiang suspension bridge 1999 (China)

WORLDWIDE RANKING

Suspension Bridges

RANK	NAME OF THE BRIDGE	COUNTRY	TOTAL LENGTH (km)	MAIN SPAN (km)	TOWER HEIGHT (m)	DECK WIDTH (m)	MAIN SPAN DECK AREA (m^2)	NOTES
1	Akashi Kaikyo Bridge	Japan	3.9	1,991	298 – ST	36	70,690	Motorway – 2x3
2	Xihoumen Bridge	China	2.6	1,650	211 – RC	25	40,425	Motorway – 2x2
3	Great Belt Bridge	Denmark	2.7	1,624	254 – RC	31	50,344	Motorway – 2x2
4	İzmit Bay Crossing	Turkey	2.7	1,550	234 – ST	36	55,645	Motorway – 2x3
5	Yi Sun-sin Bridge	South Korea	2.3	1,545	270 – RC	36	55.620	Motorway – 2x2
6	Runyang Bridge	China	2.4	1,490	215 - ST	45	67,440	Motorway – 2x3
7	Nanjing 4th Yangtze Bridge	China	5.4	1,418	229 – RC	38	54,167	Motorway – 2x3
8	Humber Bridge	UK	2.2	1,410	156 – RC	29	40,185	Motorway – 2x2
9	3. Bosphorus Bridge	Turkey	2.2	1,408	322 – RC	59	83,072	Motorway – 2x4 Railway – 2x1

WORLDWIDE RANKING

Cable-stayed Bridges

RANK	NAME OF THE BRIDGE	COUNTRY	TOTAL LENGTH (km)	MAIN SPAN (km)	TOWER HEIGHT (m)	DECK WIDTH (m)	MAIN SPAN DECK AREA (m^2)
1	3. Bosphorus Bridge	Turkey	2,2	1,408	322 – RC	59	83,072
2	Russky Bridge	Russia	1,9	1,104	321 – RC	30	32,568
3	Sutong Bridge	China	2,1	1,088	306 – RC	41	44,608
4	Stonecutters Bridge	China	1,6	1,018	298 – RC	53	54,259
5	E'dong Bridge	China	6,2	926	243 – ST	38	35,188
6	Tatara Bridge	Japan	1,5	890	220 – ST	31	27,412
7	Normandy Bridge	France	1,3	856	215 – RC	24	20,201
8	Jiujiang Fuyin Bridge	China	-	818	244 – RC	29	23,803
9	Jingyue Bridge	China	5,4	816	265 – ST	25	19,992

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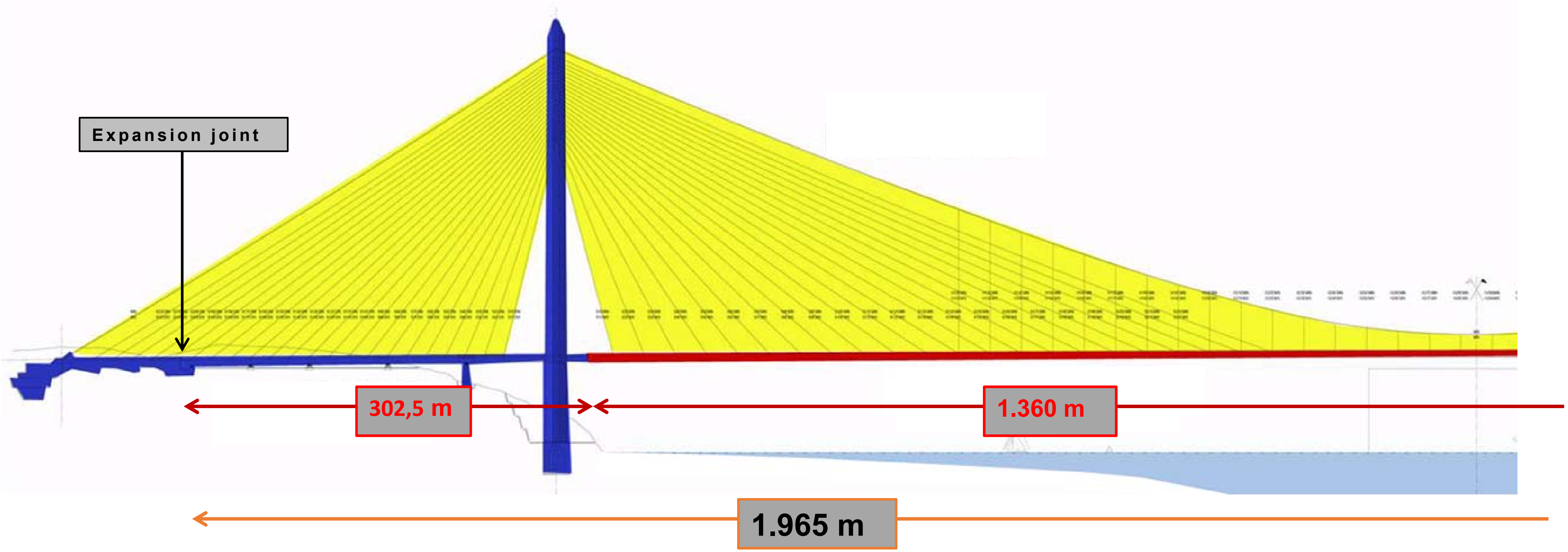
3rd BOSPHORUS BRIDGE

The bridge is composed of three parts:

- **A cable stayed/suspended steel deck of L= 1,360 m.**
- **Extensions at both ends, as prestressed post-tensioned cast-in-situ concrete.**
  Side Spans, with a length of: Ls= 2x45m + 2x60m + 68.5m + 24 = 302.5 m.
- **Overall length of the Bridge becomes Lo= 1,360 + (2 x 302.5) = 1,965 m.**



UNEXPECTED ALTERNATIVE
TO CROSS THE BOSPHORUS

Ice in the Bosphorus the 23rd February 1954

3rd BOSPHORUS BRIDGE - EXECUTED IN ONLY 40 MONTHS

PROJECT CONTRACT

B.O.T. CONTRACT – BUILD OPERATE TRANSFER

ICA's Responsibilities

- Project Finance
- Design
- Procurement
- Construction
- Operation
- Maintenance During Operation Period
- Transfer of Motorway to KGM at the end of Contract Duration

KGM's Responsibilities

- Expropriation and Land Allocation
- Revenue Payment to ICA During Operation Period
- Assistance in Approvals from Major Interfaces

PROJECT STRUCTURE

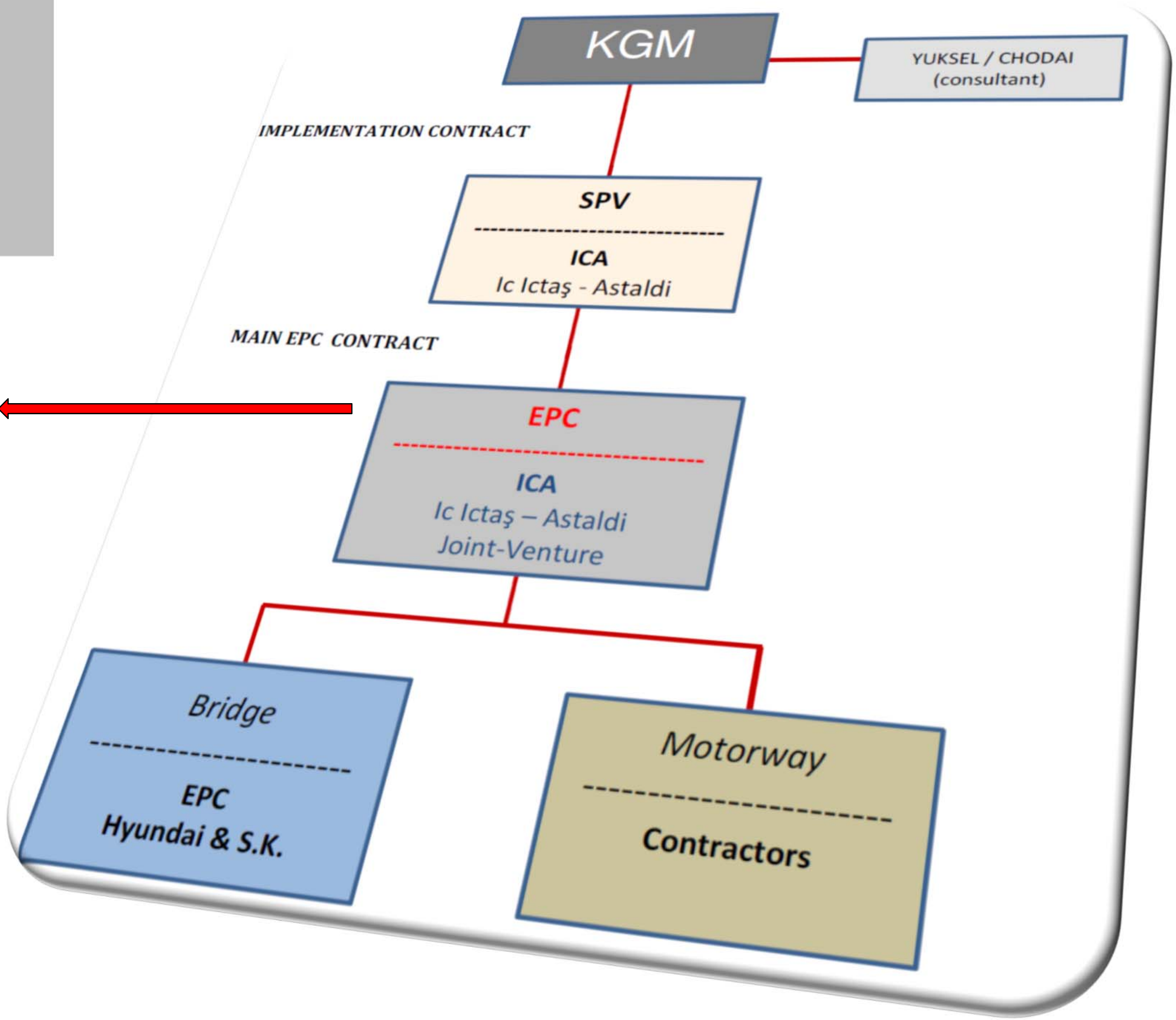
CONTRACTUAL VALUE

USD 2.878.065.220

BRIDGE	805.833.619 $
MOTORWAY	2.072.231.601 $

EPC CONTRACTOR

ICA : IÇTAŞ and ASTALDI



The Groundbreaking Ceremony was held on 29.05.2013

BB3 project has been awarded, as BOT contract, by KGM (Turkish National Autority) to a Joint Venture named **ICA** between:

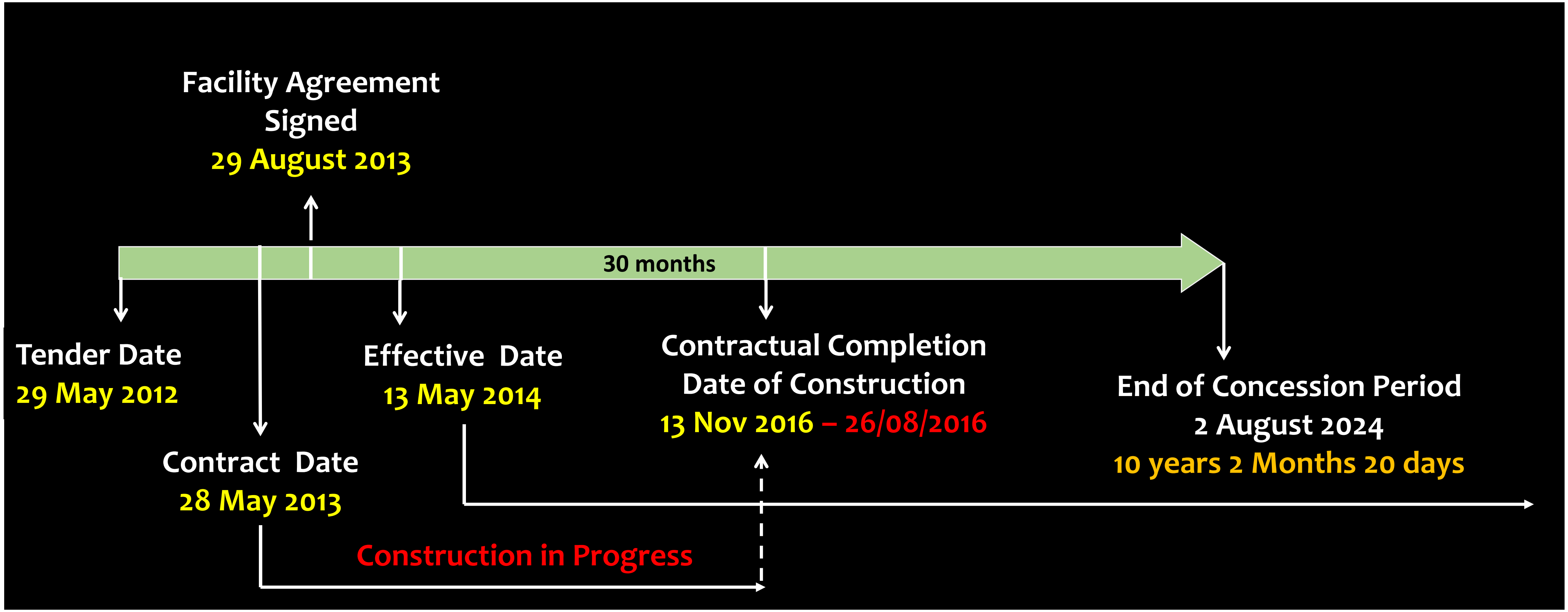
- **IÇTAŞ INŞAAT (Turkey)**
- **ASTALDI SPA (Italy)**

The name of the 3rd bridge is **Yavuz Sultan Selim Ist**

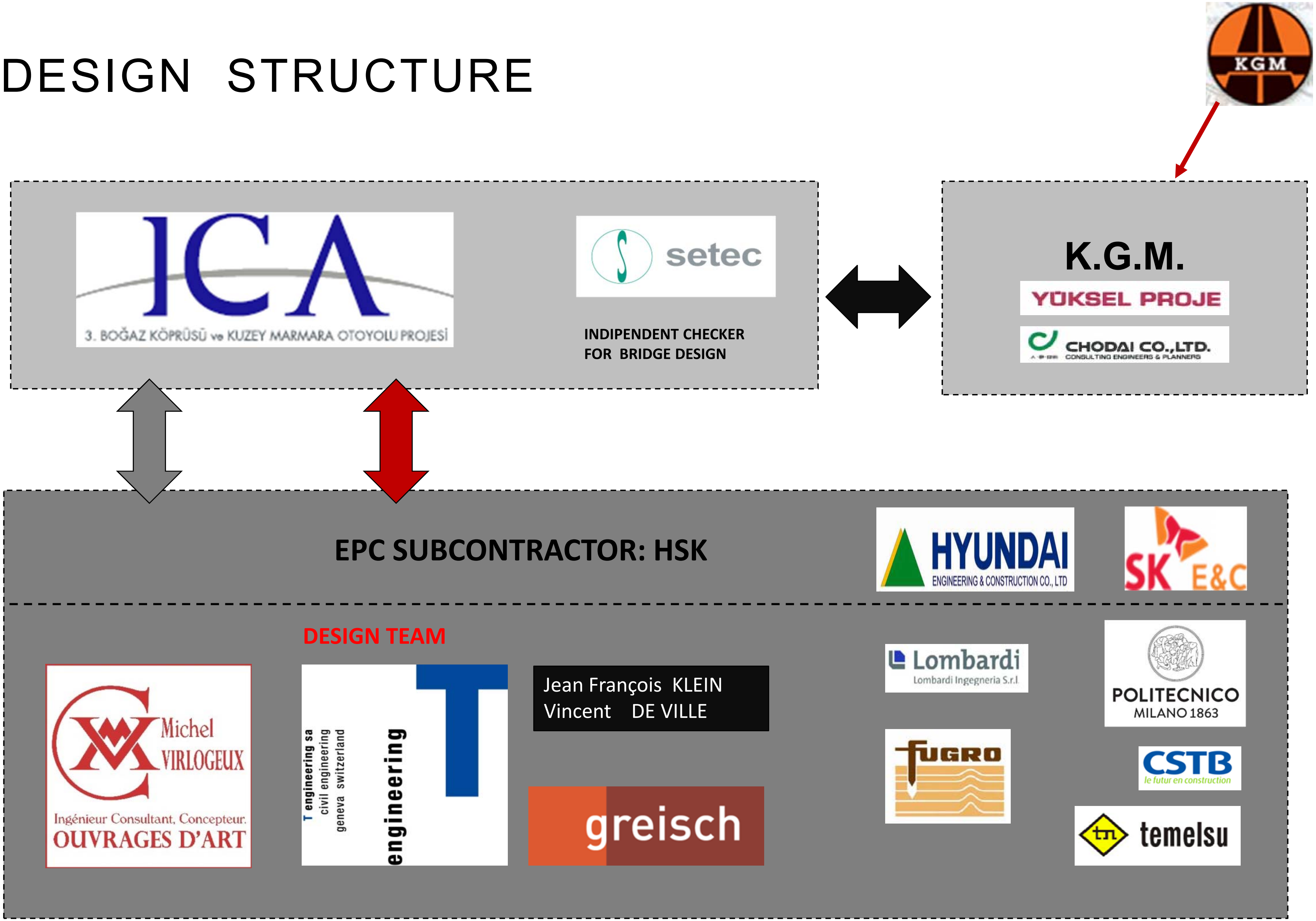
Open Ceremony 26^{th} August 2016

PROJECT TIMELINE

- The **construction duration is 30 months** from the effectiveness date of the contract
- Total **concession period is 10 Years, 2 Months, 20 days** from the effectiveness date of contract
- End **of construction should be 13 November 2016** **(Bridge 26/08/2016)**



DESIGN STRUCTURE



FAST TRACK PROJECT

A HUGE ORGANISATION BROUGHT TO A HIGH LEVEL PERFORMANCE IN THE TWO FIRST YEARS

NOVEMBER 2012

NOVEMBER 2014

WORKERS	ICA	CONTR.	TOTAL
MOTORWAY	671	3.835	4.506
BRIDGE	**86**	**1.305**	**1.391**
MANAGMENT	114	126	240
TOTAL	**871**	**5.266**	**6.137**

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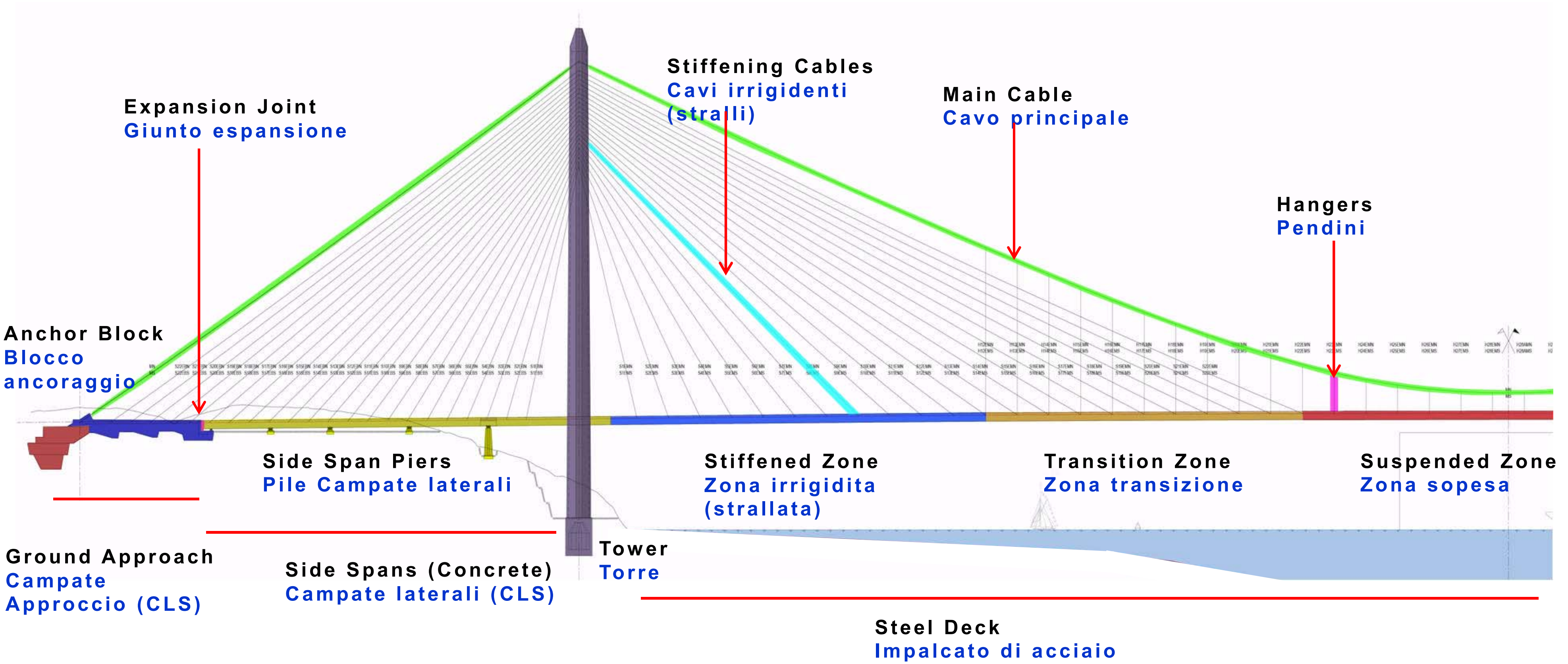
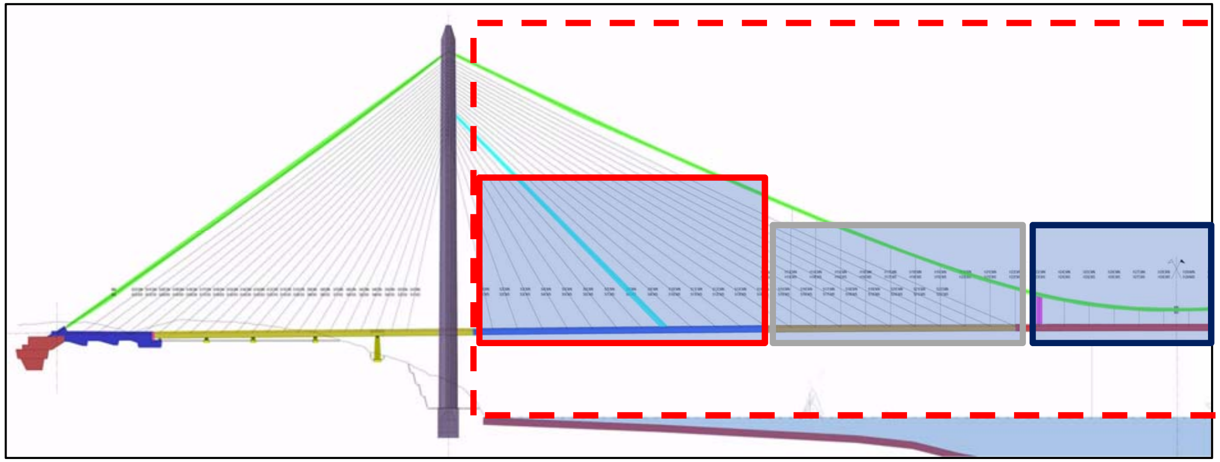
PROJECT DESCRIPTION

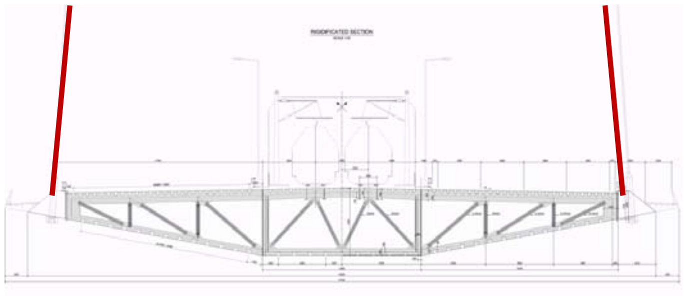


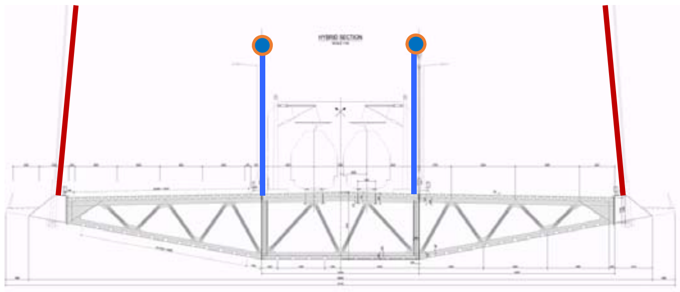
PROJECT DESCRIPTION

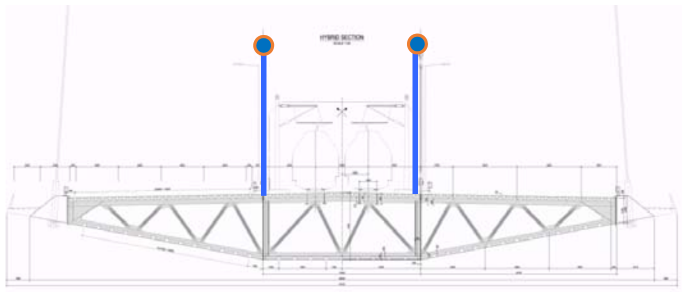
MAIN SPAN (STEEL DECK)



Stiffening zone	Transition zone	Suspended zone
Stiffening cables in extreme sides	Stiffening cables in extreme sides Hangers in the middle	Main cables hangers in central zone near railway



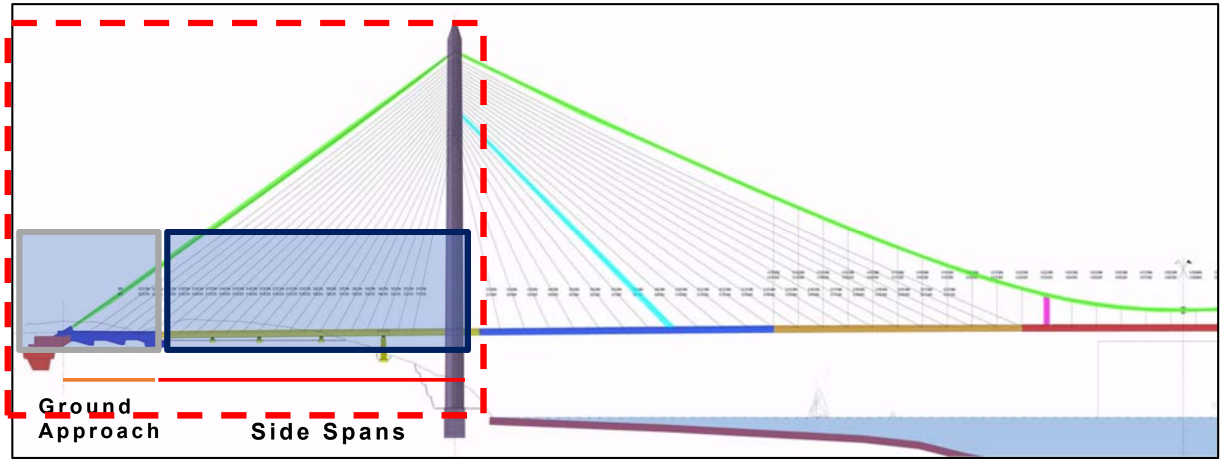




PROJECT DESCRIPTION

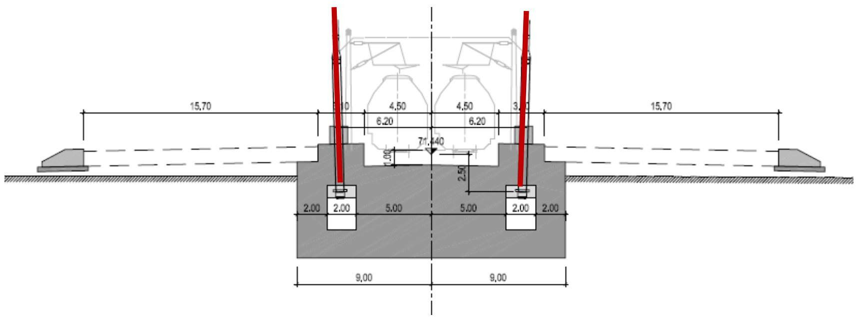
PROJECT DESCRIPTION

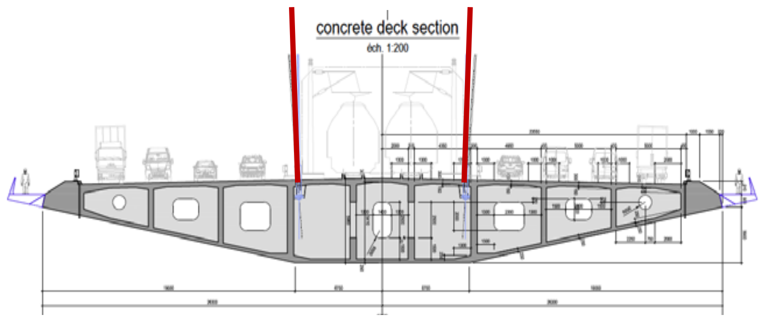
BACK SPAN (CONCRETE DECK)



Ground approach zone
Stiffening cable in the internal zone, near the railway

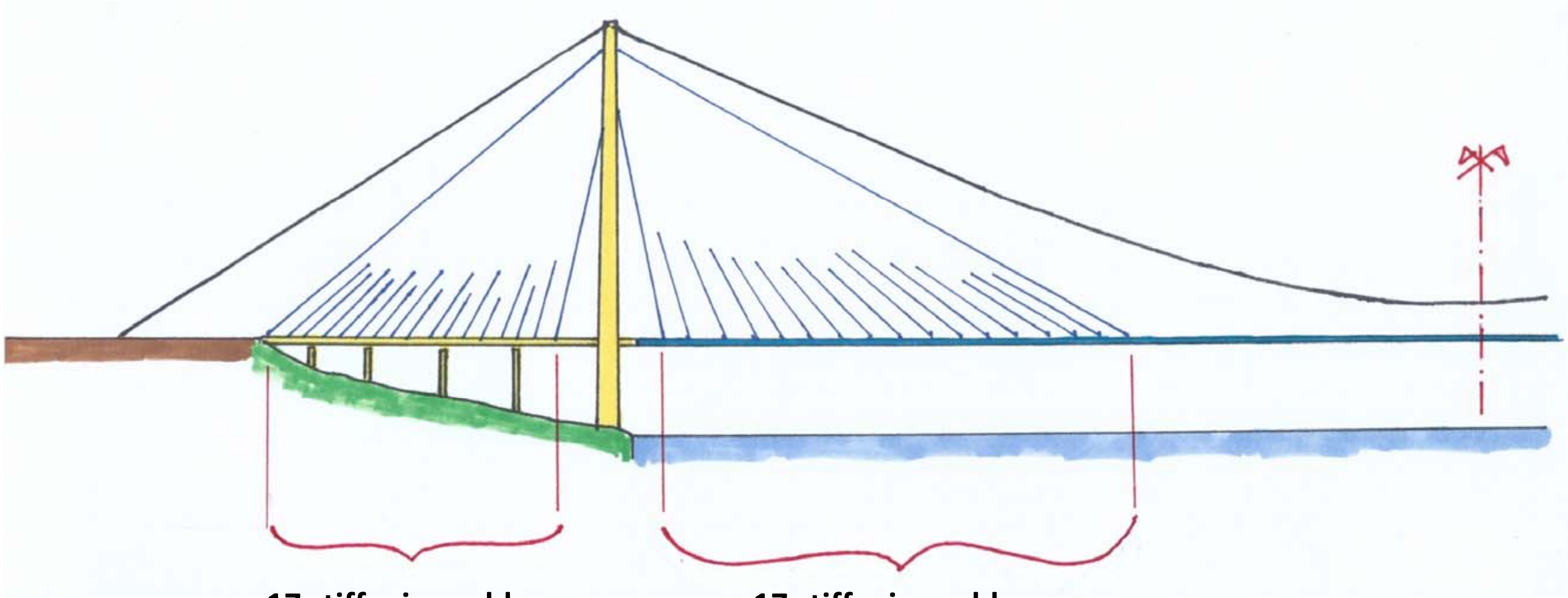
Side span zone
Stiffening cable in the internal zone, near the railway



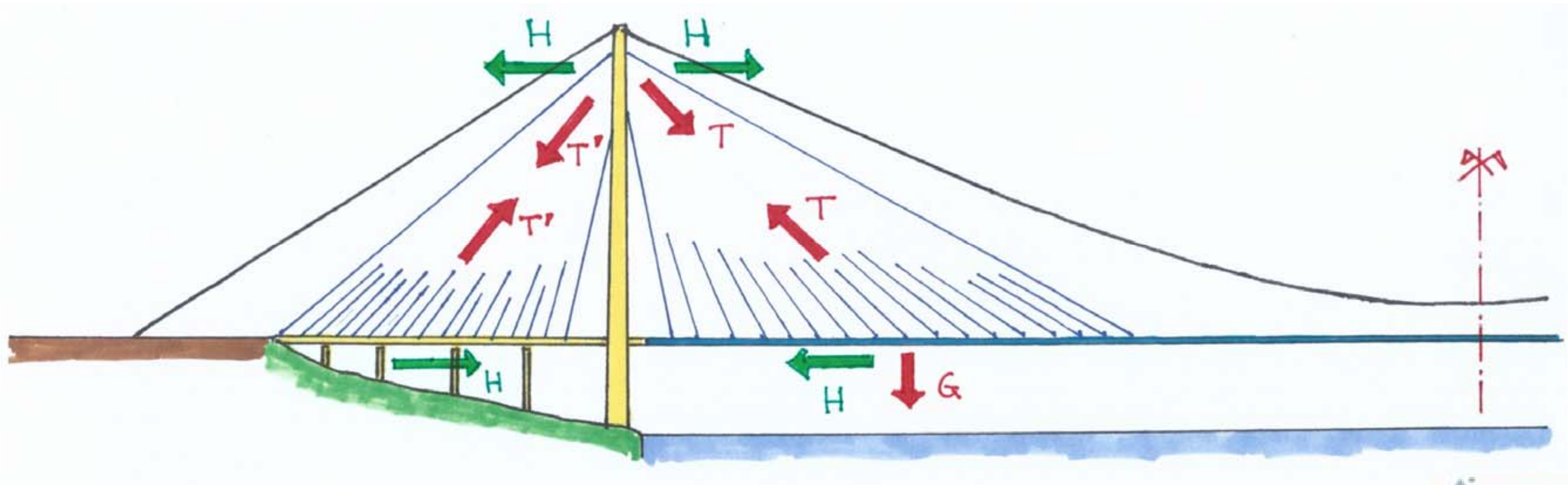


PROJECT DESCRIPTION

Balance of longitudinal forces



17 stiffening cables **17 stiffening cables**



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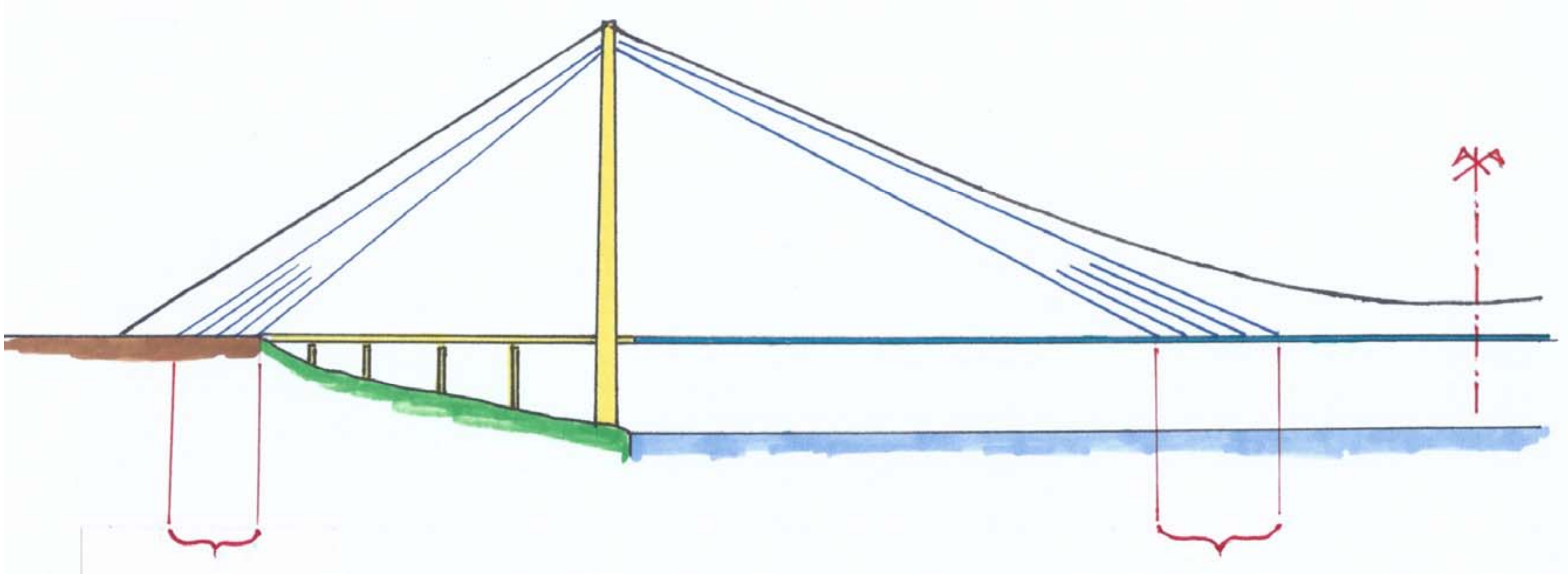
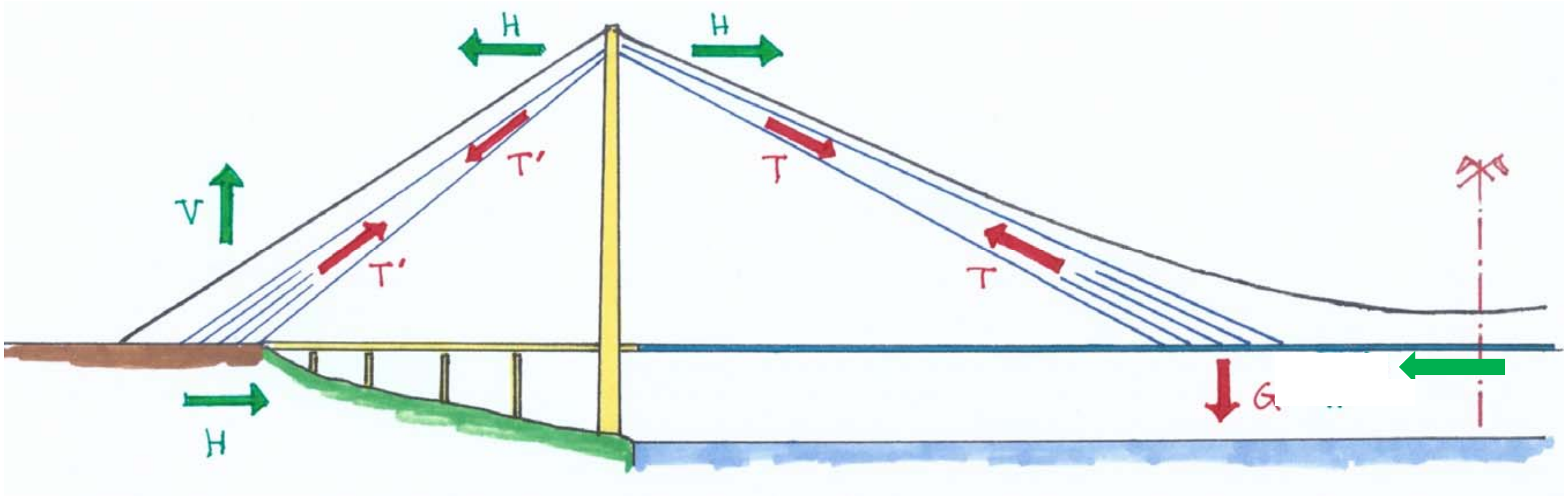
PROJECT DESCRIPTION

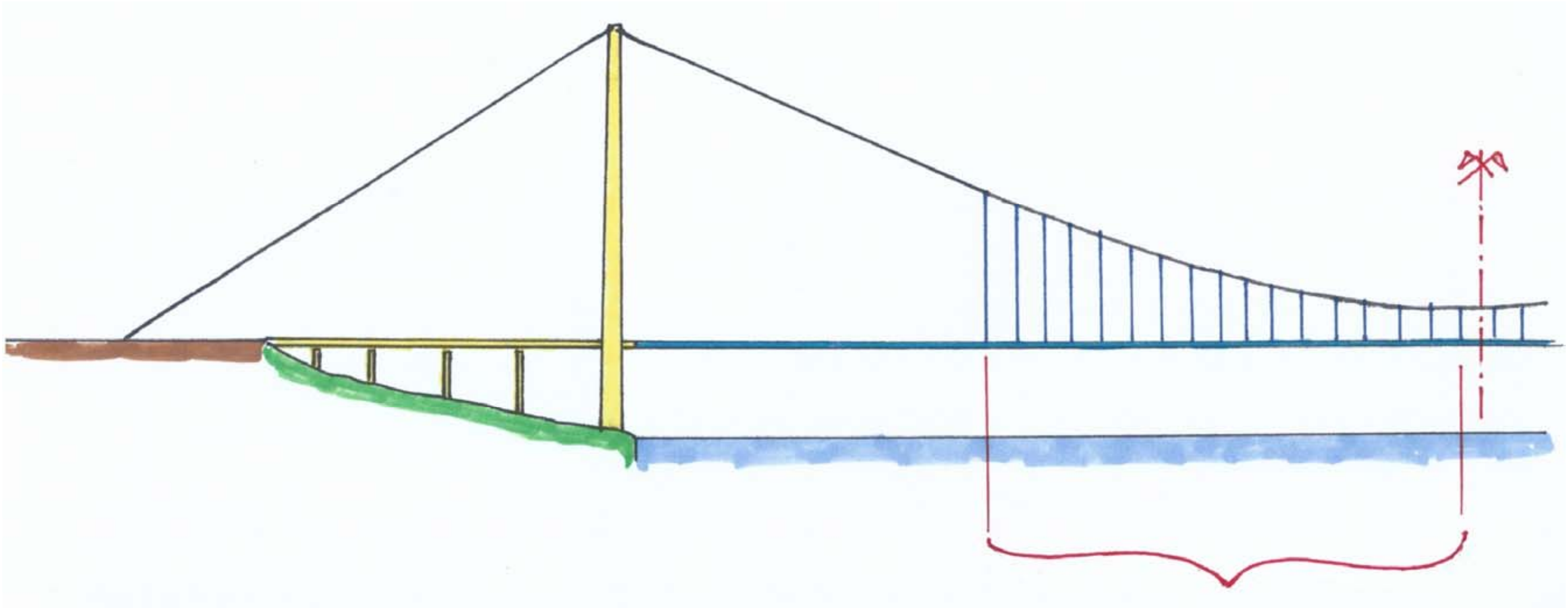


5 stiffening cables

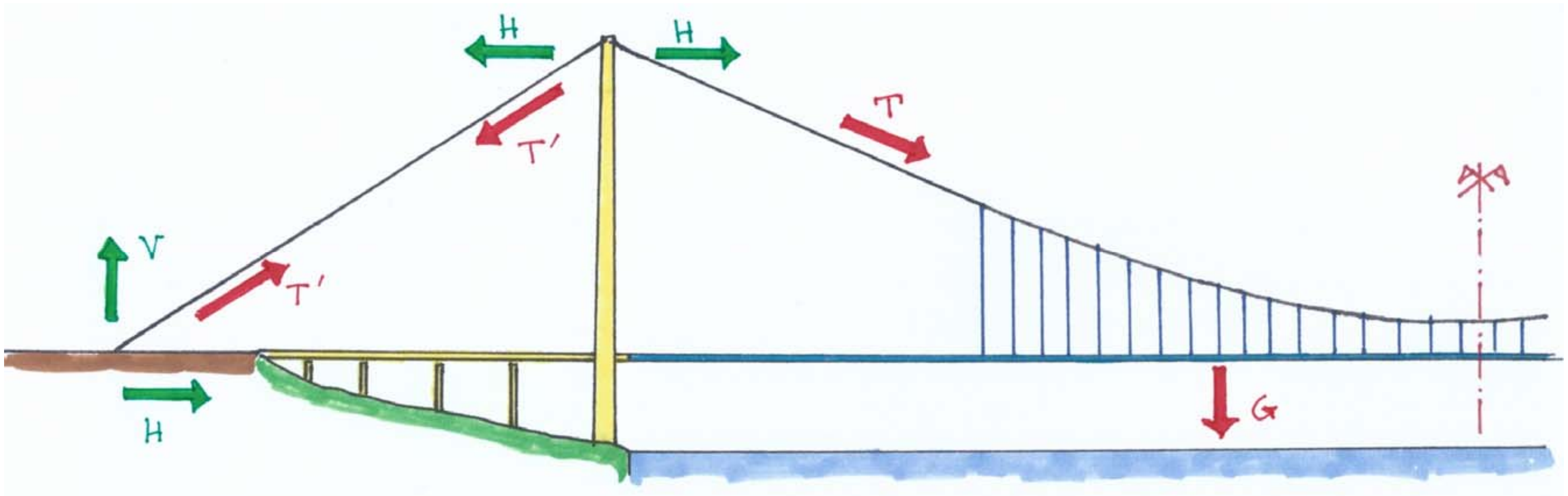
5 stiffening cables



PROJECT DESCRIPTION

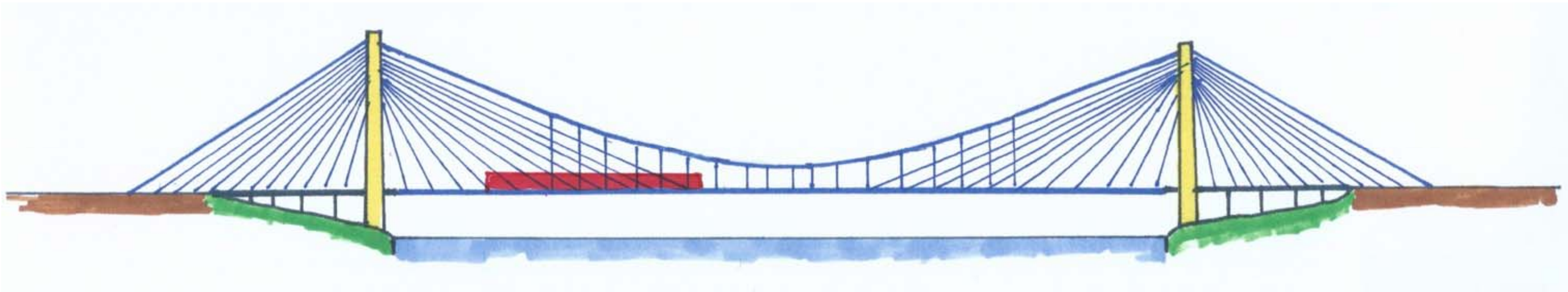


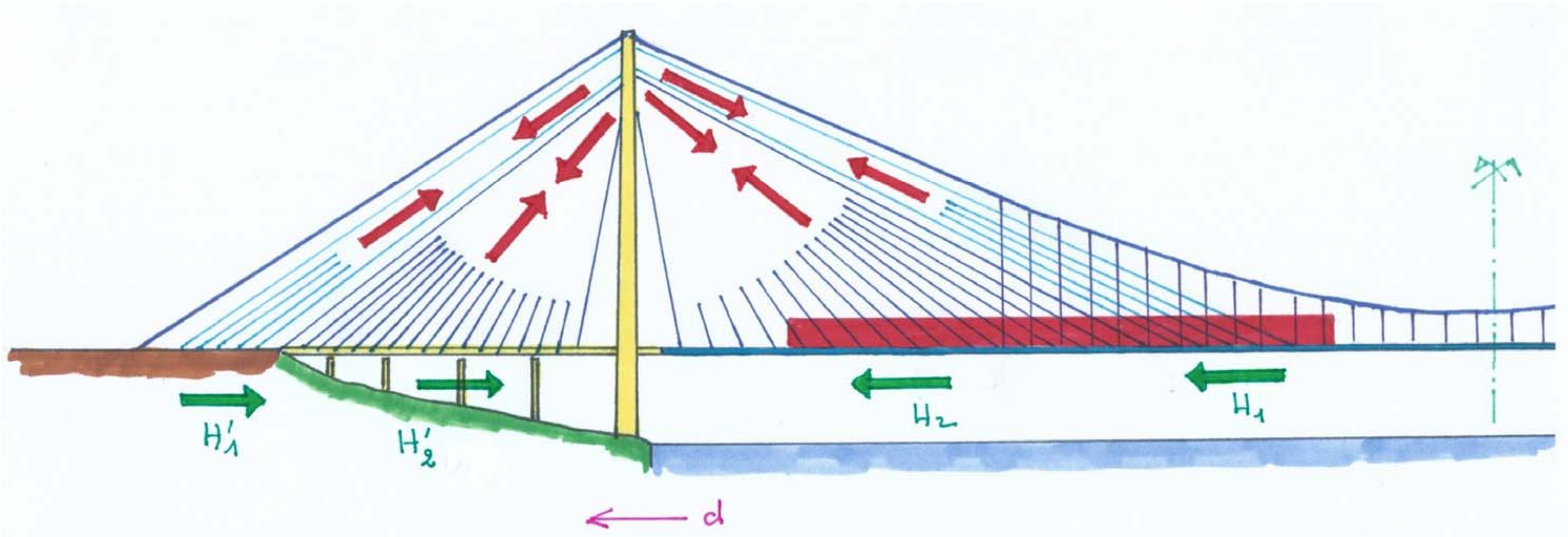
17 hangers



PROJECT DESCRIPTION

Effects of unsymetrical train loads





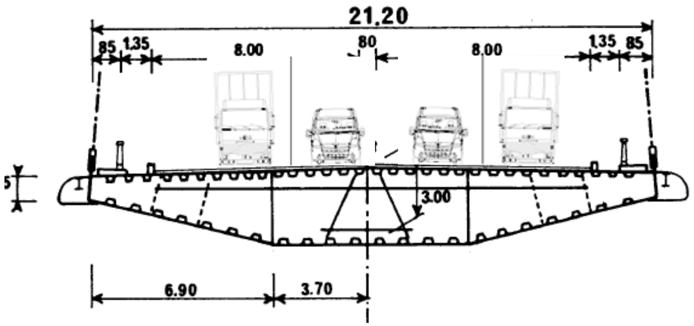
Longitudinal displacement

DESIGN CRITERIA

LOADS

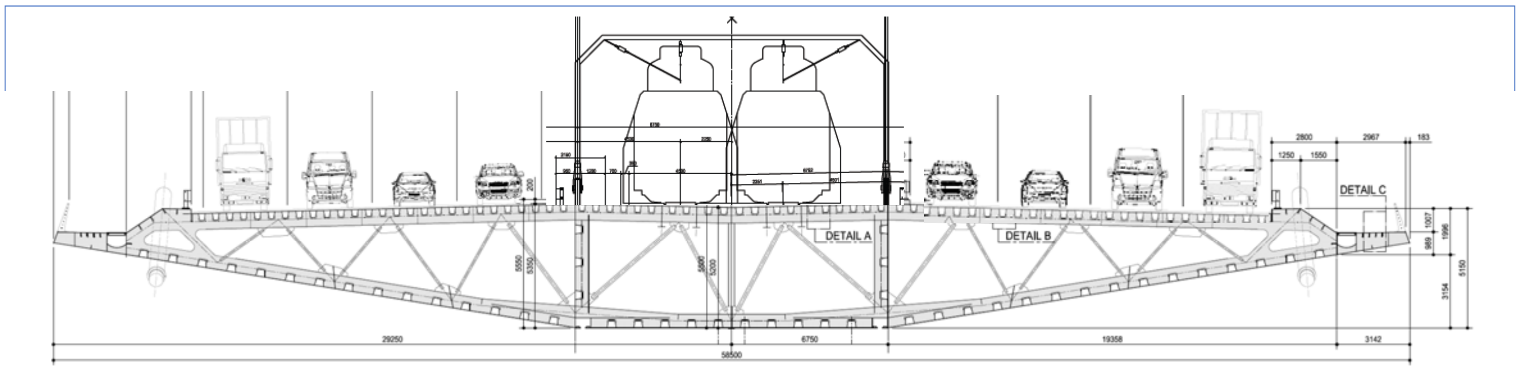
Normandy bridge

Permanent loads: 130 kN/ml
Distributed loads: 36 kN/ml
Ratio: 0.28



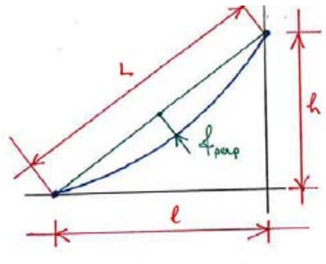
3rd Bosphorus Bridge

Permanent loads: 470 kN/ml
Distributed loads: 250.84 kN/ml
Ratio: 0.54

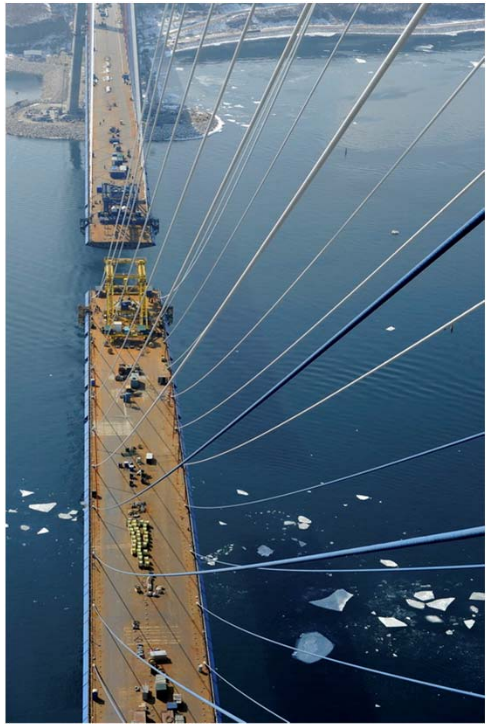


DESIGN CRITERIA

LOADS



SAG reduce from 7,50 to 5,40 m



Drawbacks:

- High level of fatigue stresses in the steel structure
- Limited tension under permanent loads in the main cable, stiffening cables and hangers (large sag and vibrations)

It is necessary to avoid overestimating live loads to reduce these drawbacks and to emphasize the bridge structural efficiency.

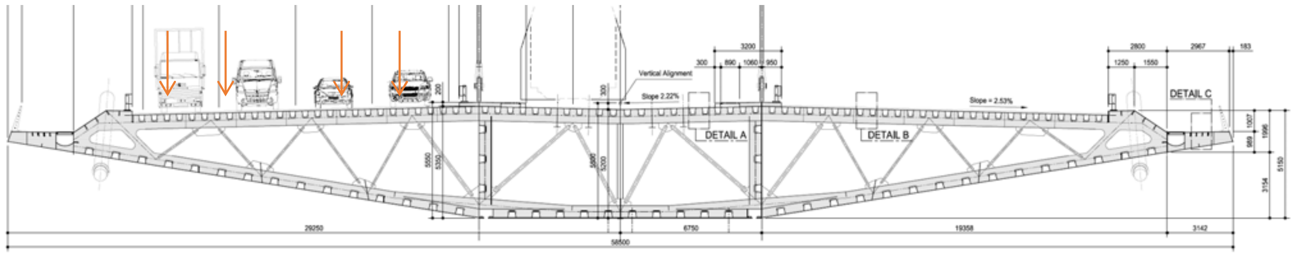
Many proposals have been done to reduce the effect of this high ratio:
- Adopt for road traffic distributed loads the length of the span (TK-BRO code);
- Suppression of sidewalk distributed loads (closed to pedestrians)
- Definition of wind velocity compatible with traffic at deck level (25 m/s);
- Increase the allowable stress to 50% GUTS (Garanteed Ultimate Tensile Stress);
- Use strands of 1’960 Mpa strength instead of 1’860 Mpa (Freyssinet) in order to reduce the size of the cables

DESIGN CRITERIA

LOADS

1. Local design – transversal direction

EUROCODES



It’s a local behaviour considering heavy concentrated loads in cross section.

Even if design is based on Eurocode concentrated load schemes, special loads (military or super heavy truck loads (540 kN)) as defined in Turkish codes have been considered.

DESIGN CRITERIA

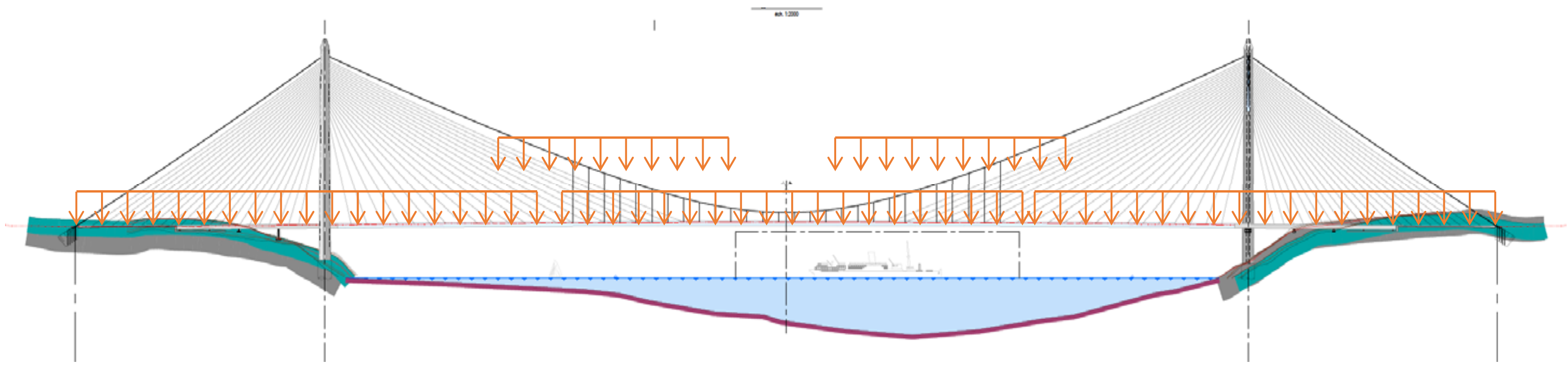
LOADS

The limits for these codes are:

EUROCODE	span length < 200 m
AASHTO	span length < 500 feet (154 m)
TURKISH	span length < 500 feet (154 m)
TK BRO (Swedish)	**NO span limit**

2. Global design - longitudinal direction

It's a global behaviour considering the complete structure.
This process is to determine forces, bending and torsional moments in the deck and in the towers in the longitudinal directions.



Design has to take into account the span length of the bridge.
It is based on a probabilistic aproach reflecting the real traffic that fully charge the main span at the same time, either in normal traffic flow or in traffic jam situation.

To avoid unrealistic loadings which can just not be physically placed on the bridge.

DESIGN CRITERIA

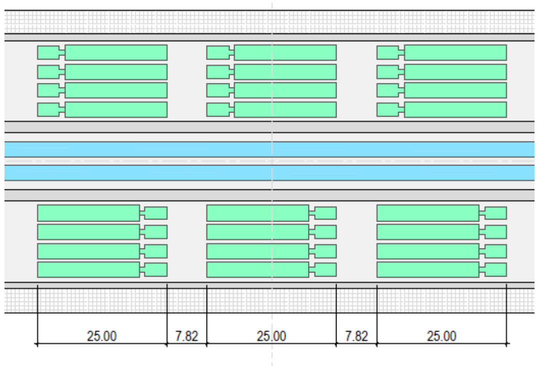
LOADS

This Swedish code for bridge design TK BRO is the only code that considers also the long spans bridged, as BB3.

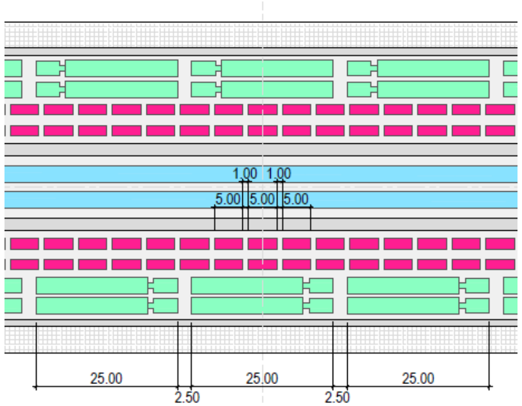
The last edition (2009) is completely based on the Eurocodes and it follows its main rules

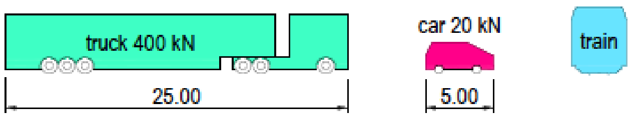
Codes	Loads
EUROCODE	97,50 kN/m
AASHTO	62,96 kN/m
TK BRO	71,40 kN/m
TURKISH	90 kN/m

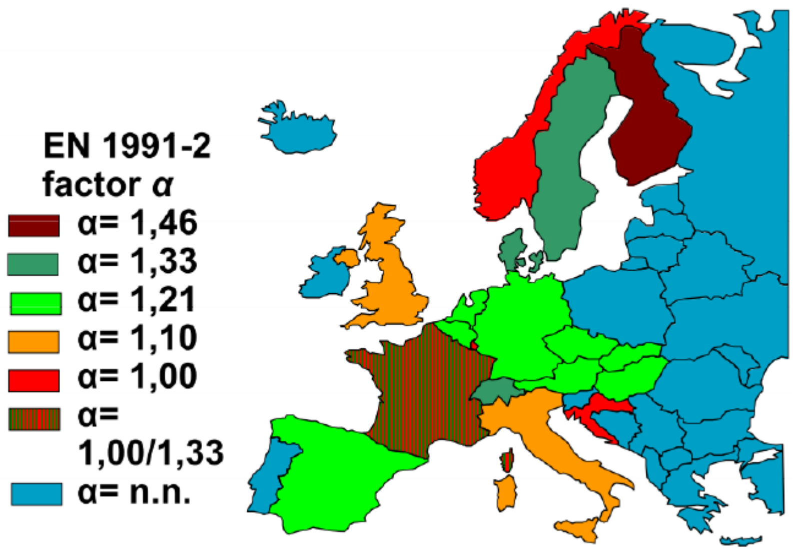
EUROCODE (4.0) = 97,50 kN/m
Span length < 200 m



TK BRO = 71,4 kN/m
Span length: no limit







Source: Seminar 'Bridge design with Eurocodes' JRC-Ispra, 1-2 october 2012.

DESIGN CRITERIA

WIND MEASUREMENT

A large program of measurements and test has been defined:

- **The climatic analyses**

  o An analysis of wind data recorded at the meteorological stations around the site

  o The installation on site of an anemometer on a mast in Asian side to measure wind data during a representative period

  o The construction of a numerical model of the site for an evaluation of the distribution of the wind velocities on the site

- **The selection of the most representative meteorological stations in the region to correlate the numerical model with the realitye observed on the site**

The mast installed by ICA since November 2012

DESIGN CRITERIA

WIND TUNNEL TESTS

The study of the interest to install or not wind screens along the deck:

- **More comfort for the car drivers**
- **Wind forces increased, multiply by a factor equal to 2,0 about.**

Dynamic analyses by evaluating the eigen vibrations modes of the bridge (in order to avoid vortex shedding and vibrations).

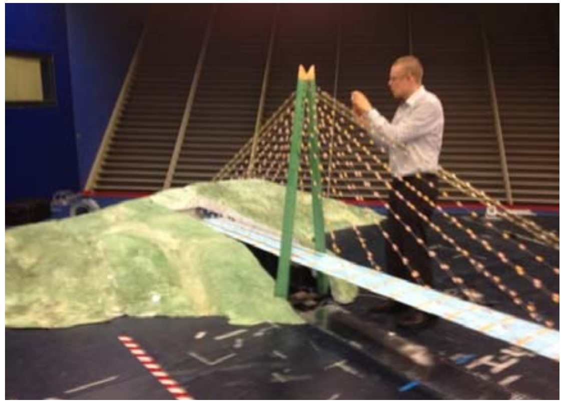
Aerodynamics analyses

Deck model scale 1/150

"Wind test" have been executed in CSTB (Nantes) and in Politecnico di Milano (Prof. Diana) and Nantes laboratories since begin 2013, on partial and full scale model for all the construction stages and the final stage.
Final wind tests have been performed on last December in order to check the wWind shield and profile and the aerodynamic damping in torsion

POLITECNICO
MILANO 1863

Rigid tower model (scale 1/150)



Full aero elastic model test (scale 1/180)

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DESIGN CRITERIA

WIND

- **The reference wind velocity is assumed as 30 m/s for the development of the design, to take the site into account and the possible increase of the wind velocity produced by the presence of the hills on both banks.**

  The parameters to define this reference wind velocity are:
  - **a return period of 100 years, an average value on a 10 min time, at 10 m above ground;**
  - **in a class II site.**

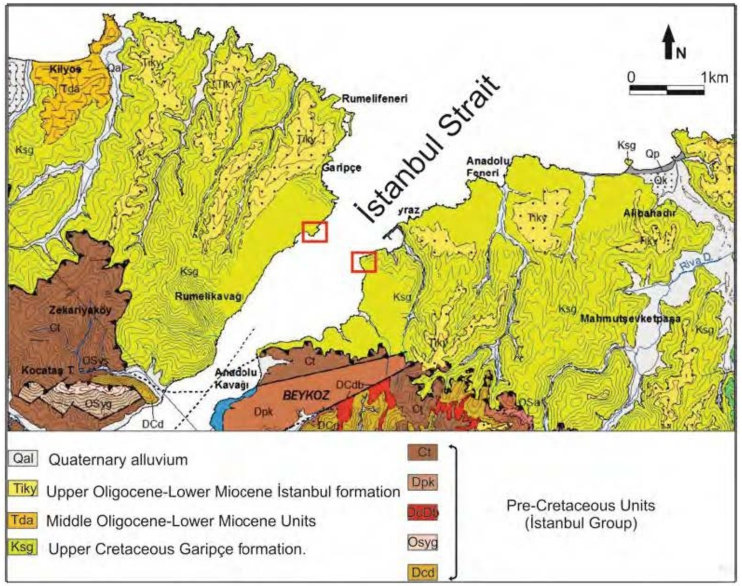
- **The mean wind speed to consider is 37 m/s**
- **At the deck level the mean wind speed v_w is equal to 46.81 m/s (~ 168 km/h)**

Return period [years]	Mean wind speed at deck level [m/s]	
50	46.81	SLS – Service
10	40.85	SLS – Building

- **The wind value defined for the closure for the traffic is 25 m/s for road, and 32 m/s for rail**

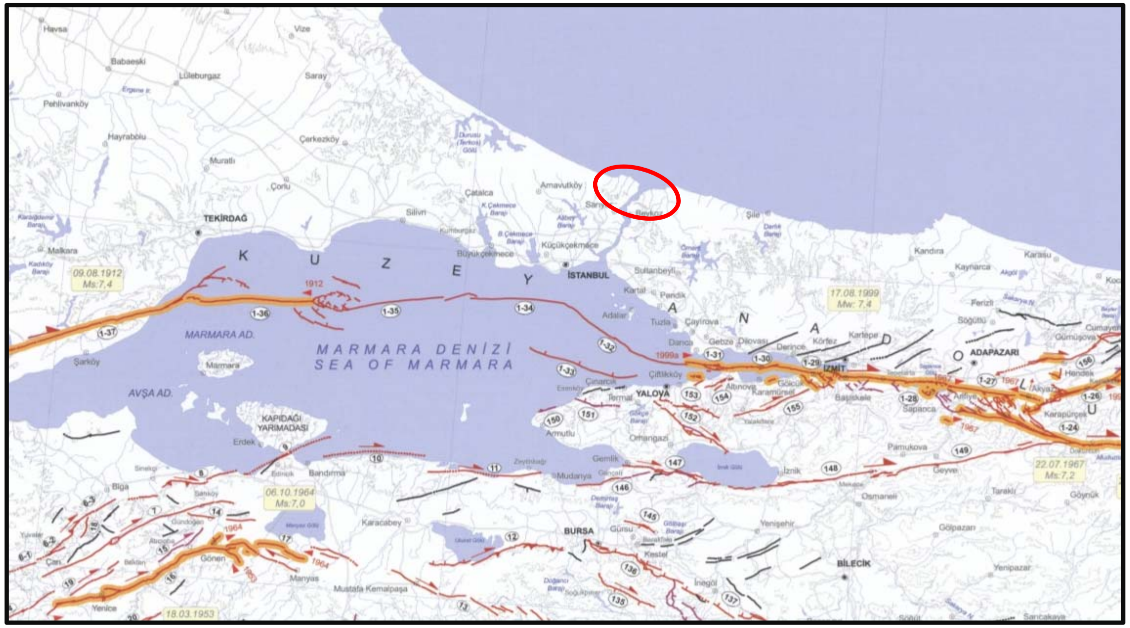
DESIGN CRITERIA

GROUND CONDITION
BRIDGE LOCATION and EARTHQUAKE

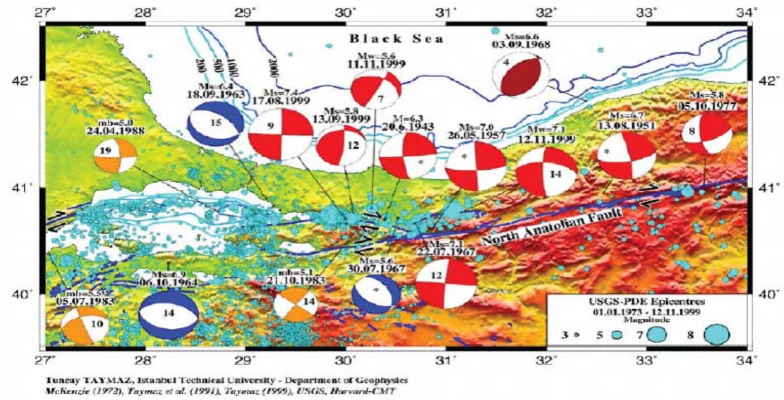


From Özgül et al. 2011. Red squares show the site locations.

Active faults (all red lines) around the Marmara Sea region on MTA Active Fault Map of Turkey 2013.
Project side is free of active fault

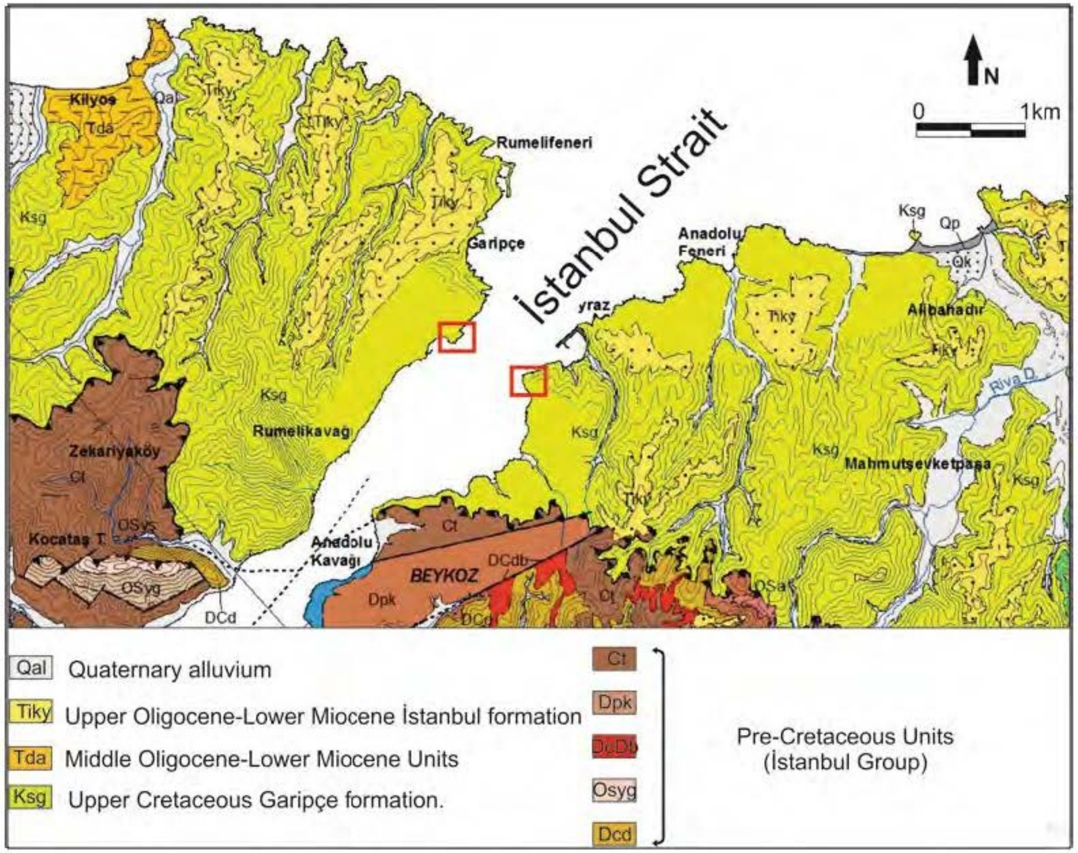


Earthquake epicenter: period 1973 – 1999.
Earthquake are distant from bridge site.



DESIGN CRITERIA

GROUND CONDITION



From Özgül et al. 2011. Red squares show the site locations.

Extensive geotechnical surveys adapted to seismic analyses have been performed by Fugro.

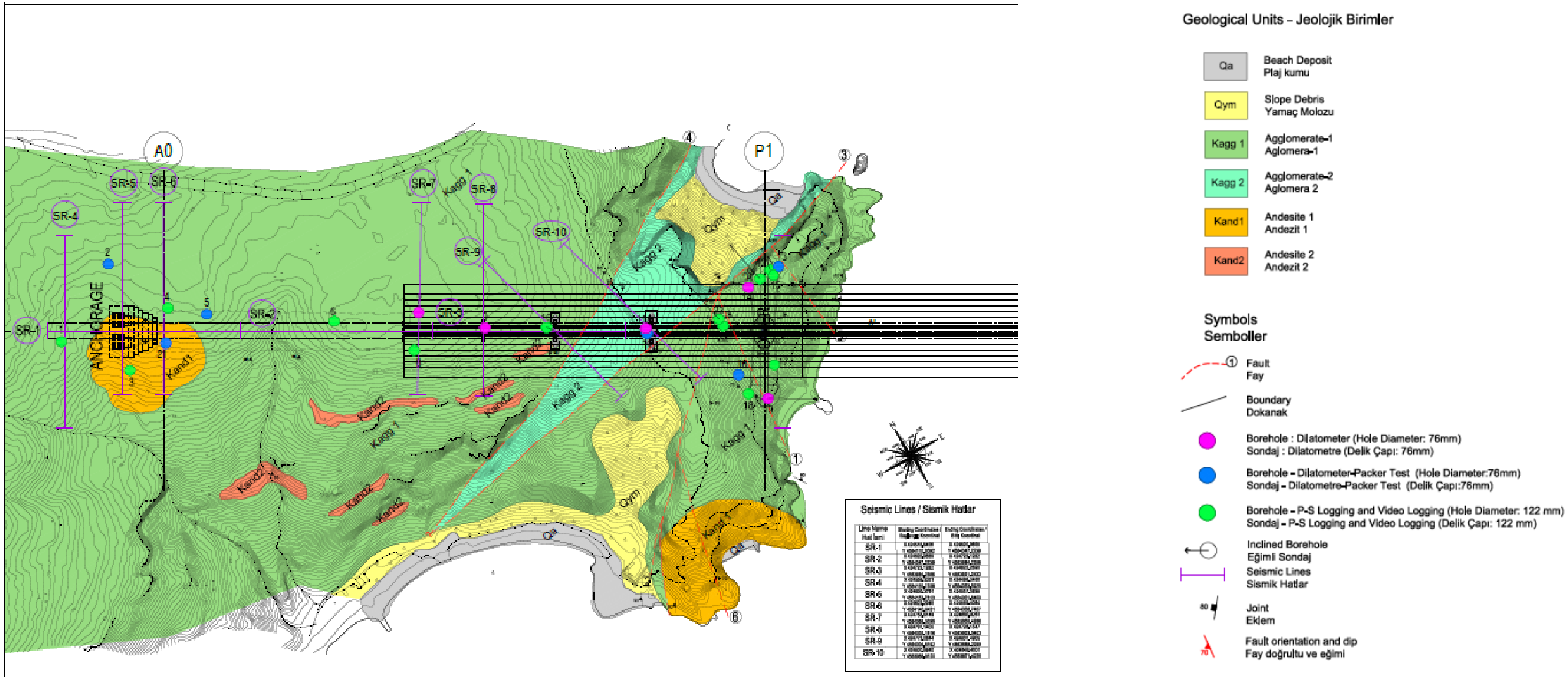
In addition Fugro has produced a series of accelerogrammes corresponding to the required seismic level, separately for each of the two banks and considering the wave propagation to the different supports.

Final seismic analyses have been performed with time history computations using these series of accelerogrammes.

Geological Map of Project Site
Upper Cretaceous Garipçe Formation

DESIGN CRITERIA

GROUND CONDITION: EUROPE SIDE



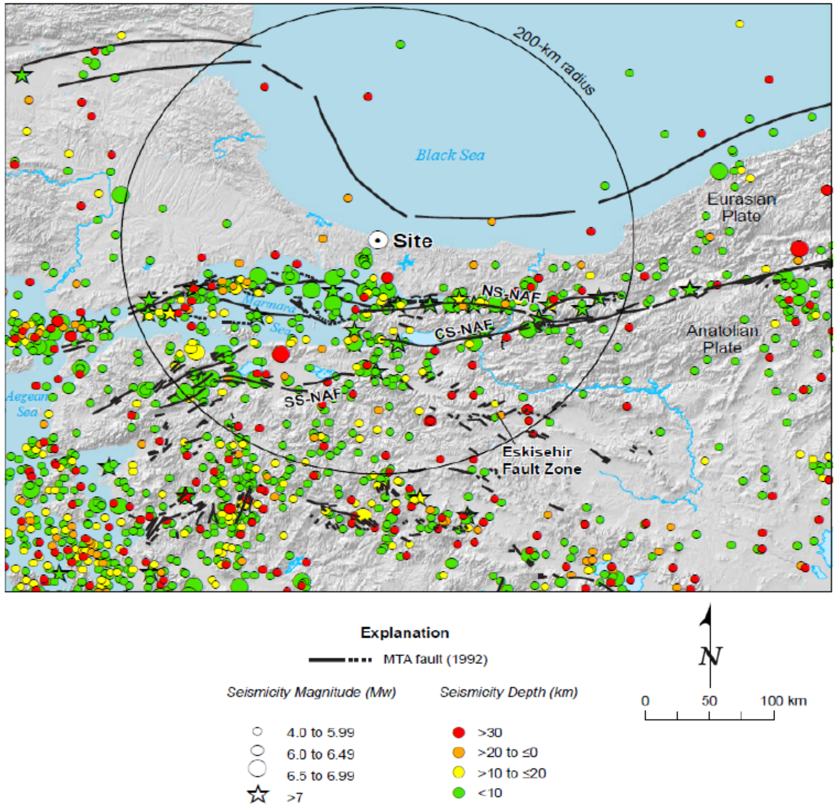
Detail Geological Map of Europe Side

Andesite 1-2: massive, strong to very strong, fresh to slightly weathered. Limited presence of joints. Ratio of clasts < 50%

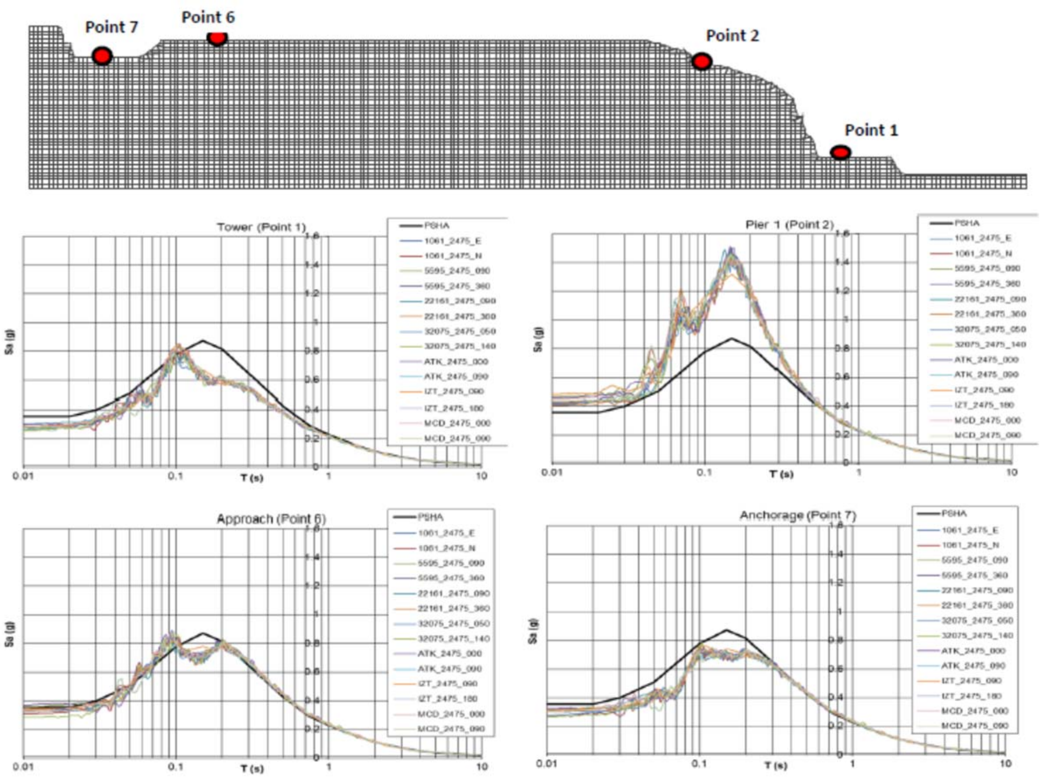
Agglomerate 1–2: massive, medium strong to strong, moderate weathered to slightly weathered. Presence of fractures. Ratio of clasts 75% - 85%

DESIGN CRITERIA

SEISMOTECTONIC SETTING

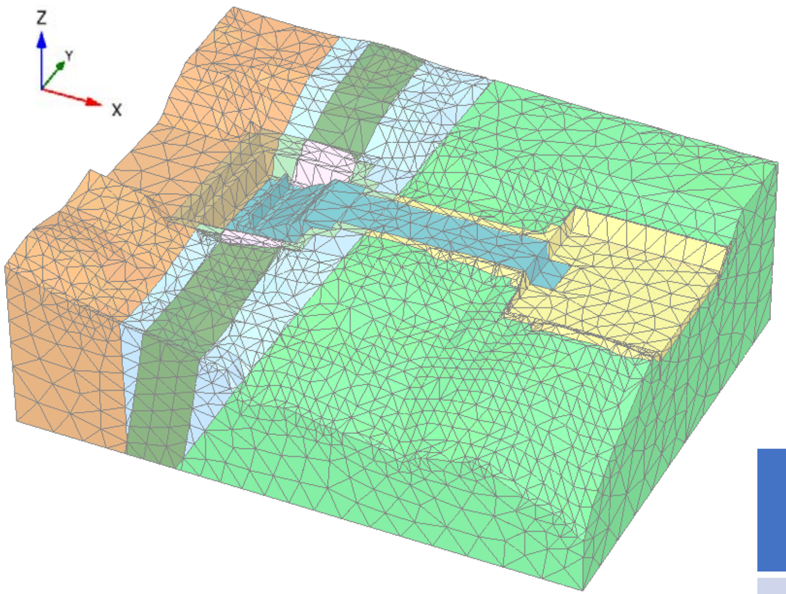


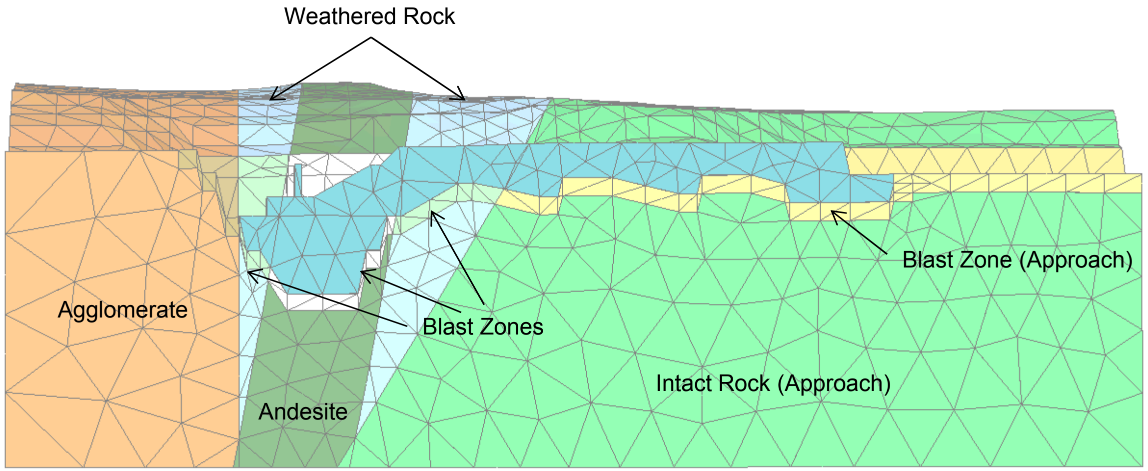
TOPOGRAPHIC EFFECTS

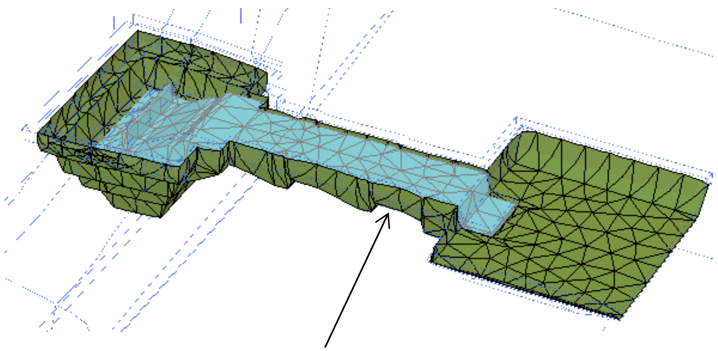


DESIGN CRITERIA

EUROPEAN SIDE MODEL







Rock Properties

	GSI	mi	Dist. Factor (D)	Compressive Strength, qu (MPa)	Young's Modulus, E (GPa)
Rock (Approach)	57	18	0 (0.5*)	45	11.9 (6*)
Weathered Rock	37	12	0 (0.5*)	8	2 (1*)
Agglomerate	51	18	0 (0.5*)	30	6.3 (3*)
Andesite	45	18	0 (0.5*)	40	8.4 (4*)
* (for blast zone)					

Interface Properties

	Cohesion (MPa)	Friction Angle (degree)	Tension (MPa)	Stiffness (GPa)
Interface (Approach)	0.75	35	0.6	6
Interface (weathered rock)	0.31	35	0.6	1
Interface (Agglomerate)	0.61	35	0.6	3
Interface (Andesite)	0.7	35	0.6	4

DESIGN CRITERIA

CONCLUSIONS

WIND

30 m/sec	Wind speed - 100 years Return period (average value 10 min time at 10 m above ground)
46,81 m/sec	At deck level (SLS service)
40,85 m/sec	SLS Building stage - 10 years Return period of construction

EARTHQUAKE

According to Turkish Regulations inspired by AASHTO two return periods have been decided:

- **2.475 years** for ULS
- **475 years** for SLS
- **75 years** for building period for ULS

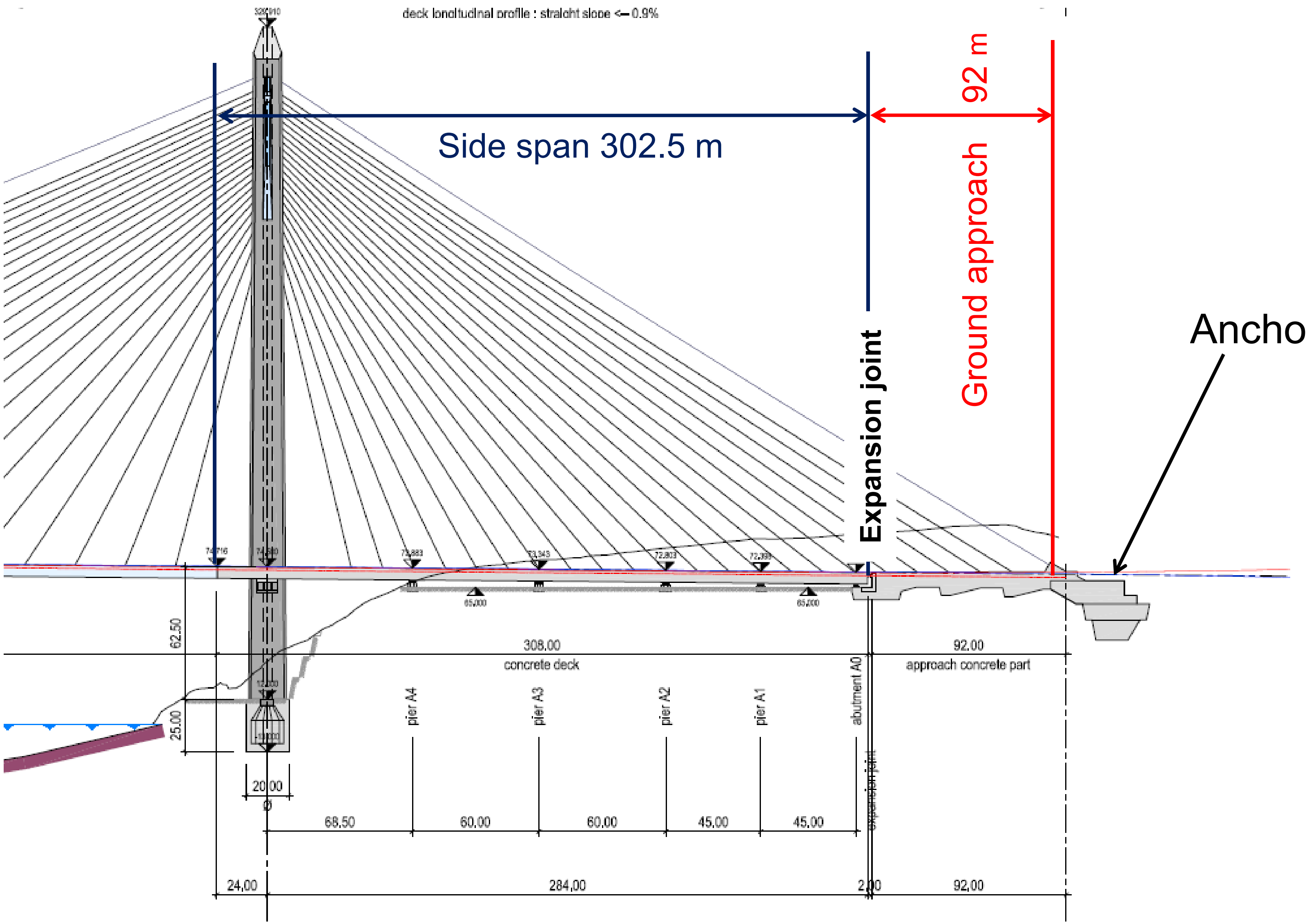
DESIGN GENERAL PRINCIPAL CONCLUSIONS

BB3 EXTREME EARTHQUAKE FORCES ARE APPROXIMATELY 50 % OF EXTREME WIND FORCES

❖ Side Span, Ground Approach & Anchorage Block

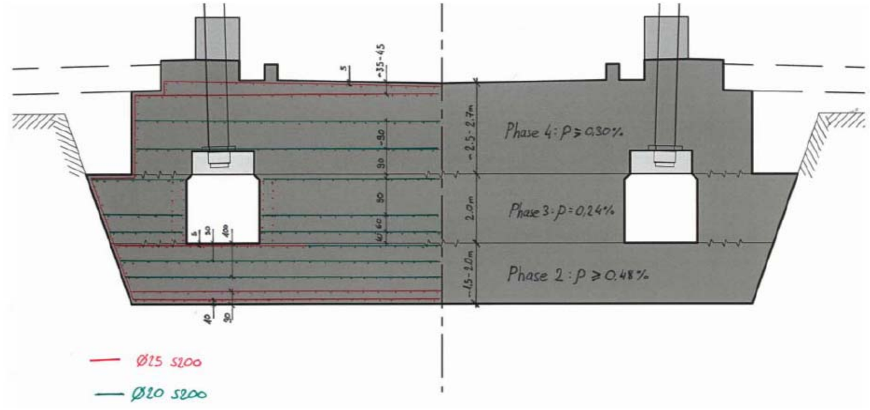
PROJECT DESCRIPTION

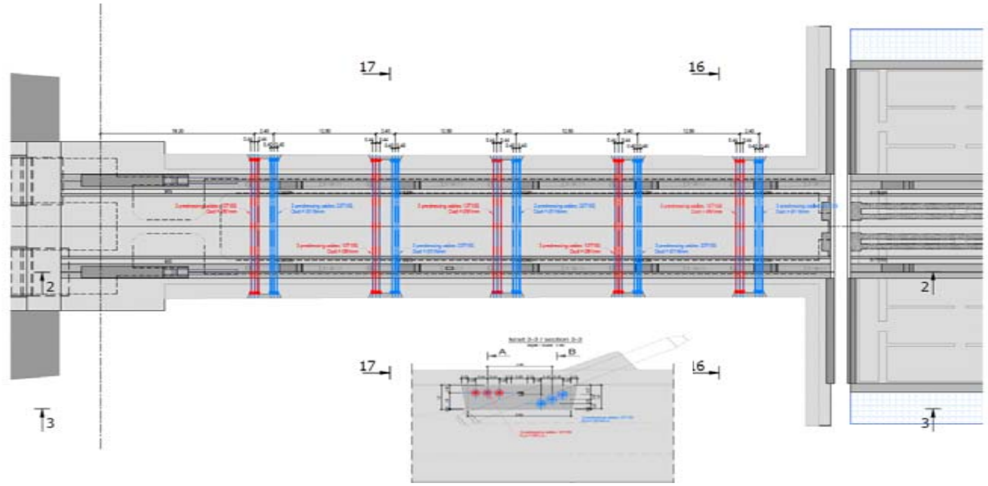
SIDE SPAN, GROUND APPROACH & ANCHORAGE BLOCK

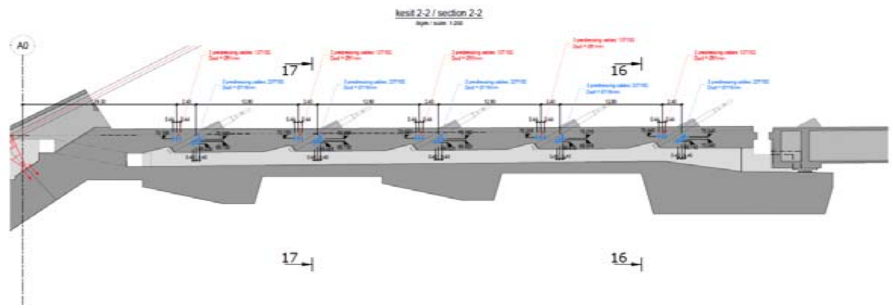


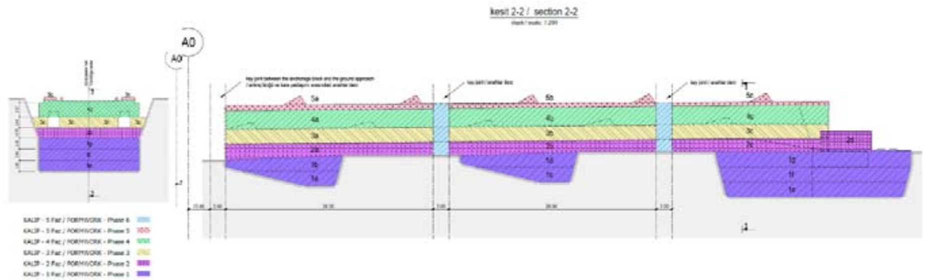
PROJECT DESCRIPTION

GROUND APPROACH









TEMPERATURE EFFECTS – CRACK CONTROL

Longitudinal behaviour – uls

- elastic and elastoplastic models (steel and concrete), rock modeled with springs;
- uls stiffening cables forces and self weigth.

→ verification of the longitudinal and vertical reinforcement needed with different rock stiffness assumptions

Anchorages areas (transversal slice) – uls

- elastoplastic models (steel and concrete);
- Accidental stiffening cable force (0.9 FGUTS).

→ design of the vertical and transversal reinforcement and prestress cables near the stiffening cables anchorages.

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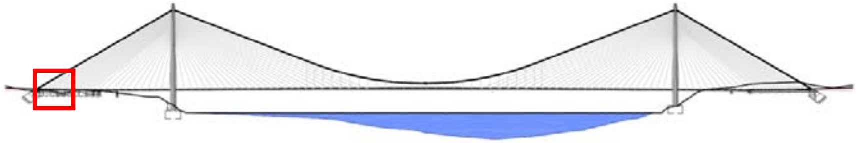
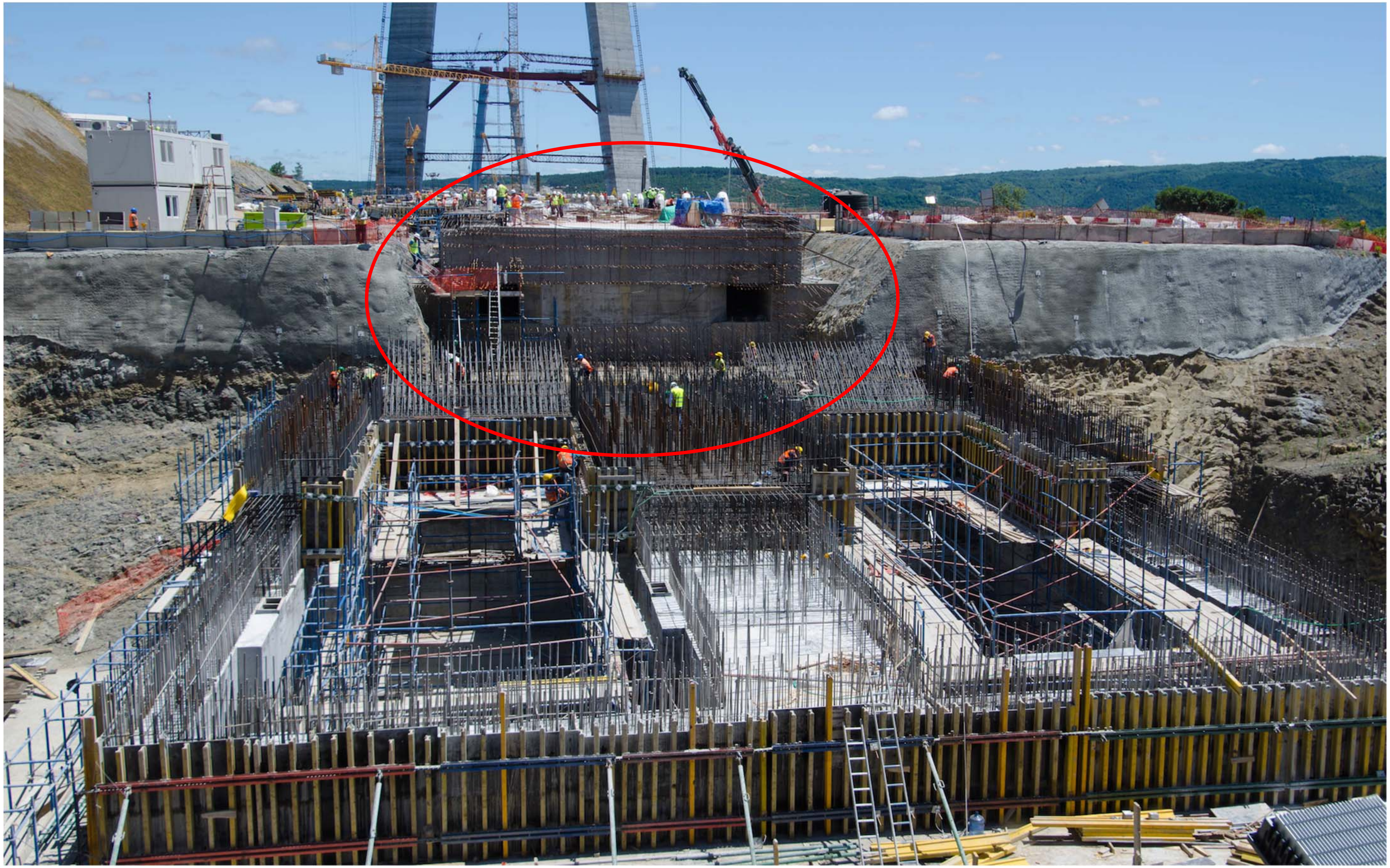
PROJECT DESCRIPTION



GROUND APPROACH



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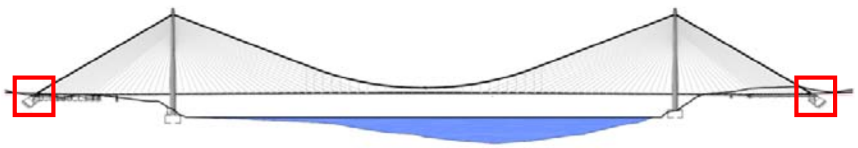
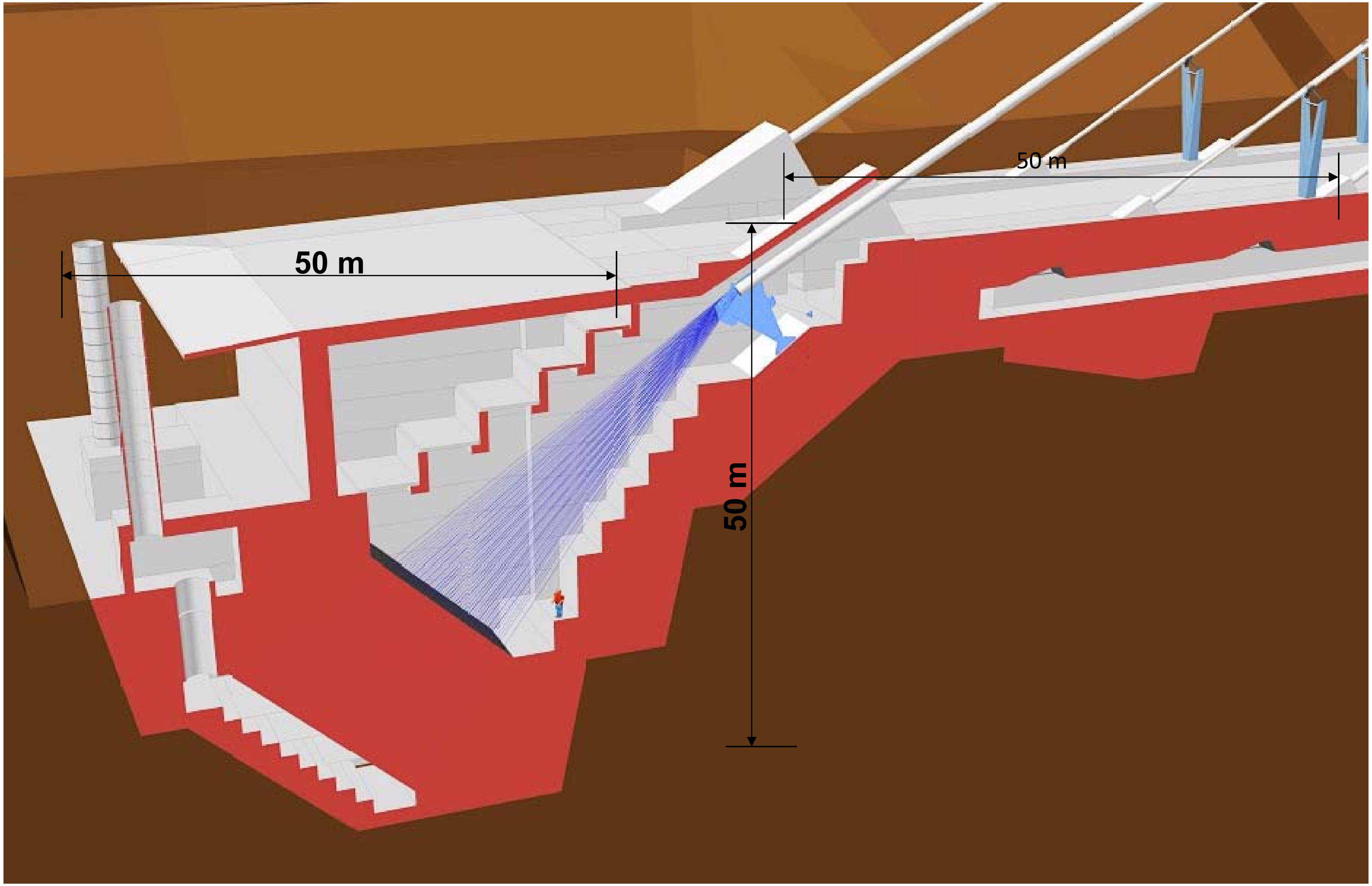


ANCHORAGE BLOCK



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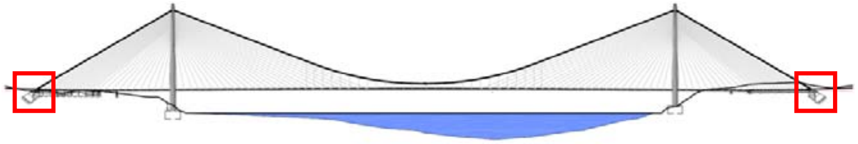
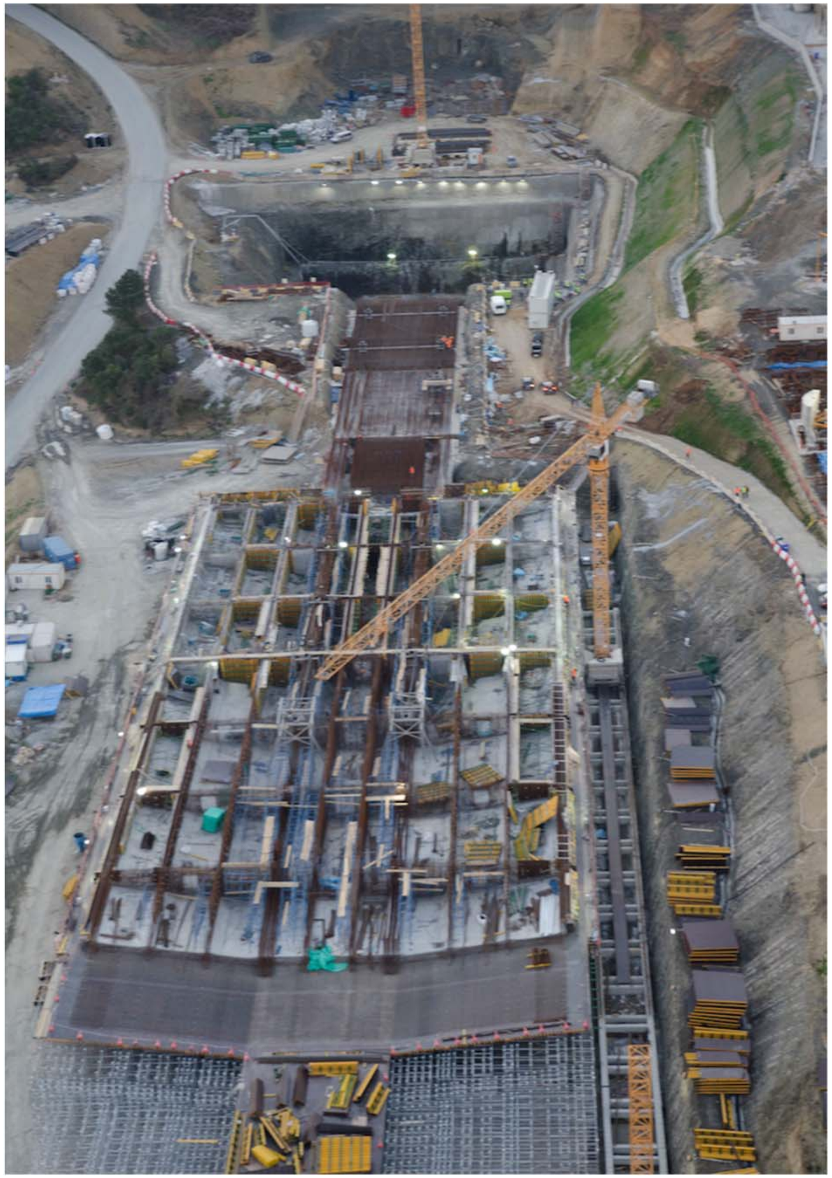
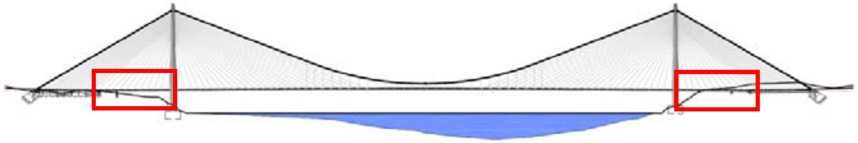


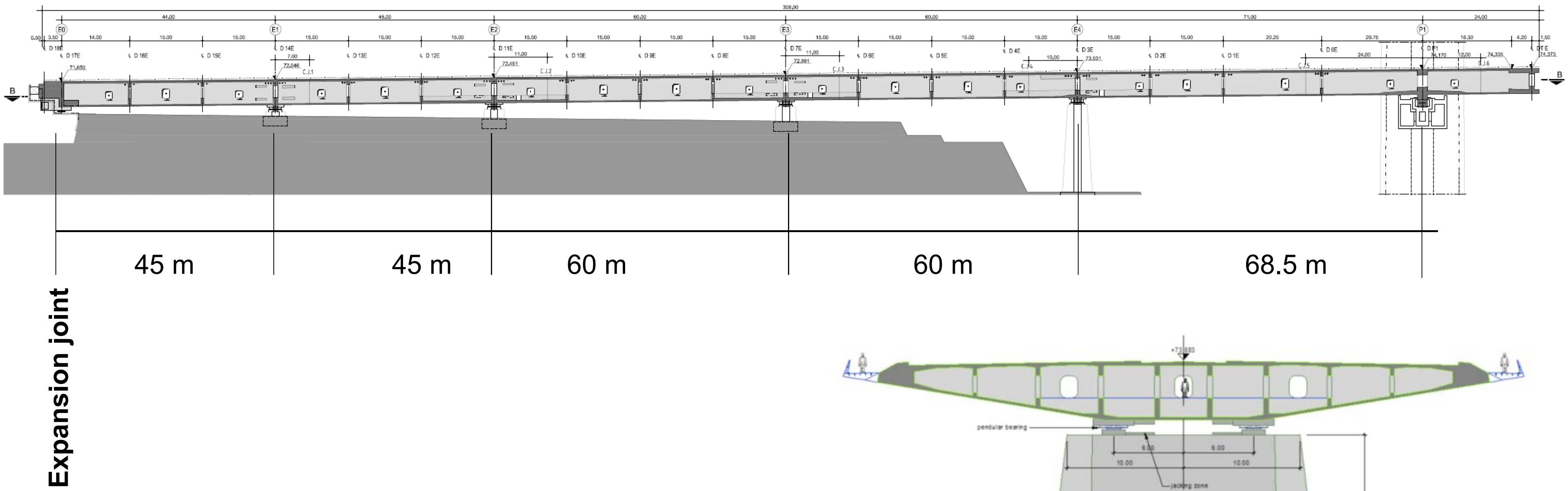
ANCHORAGE BLOCK

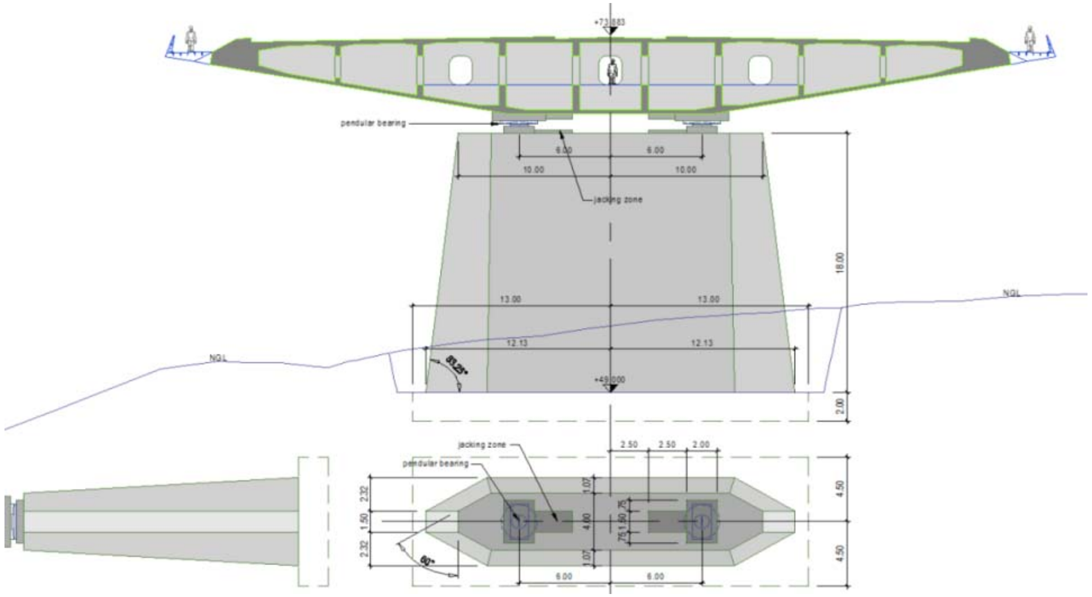


PROJECT DESCRIPTION



SIDE SPAN – EUROPE SIDE





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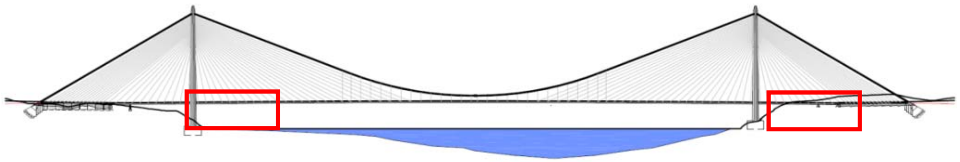
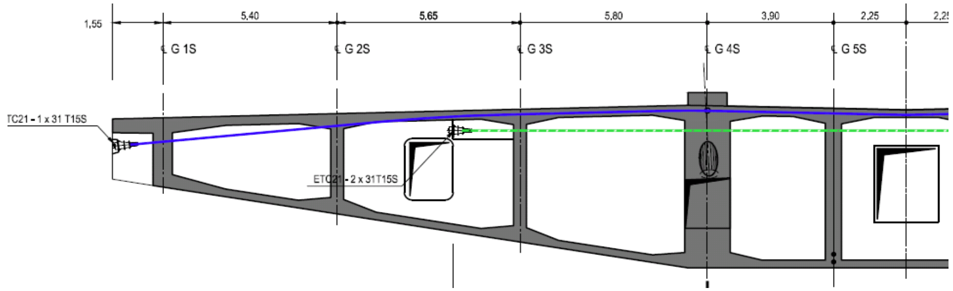
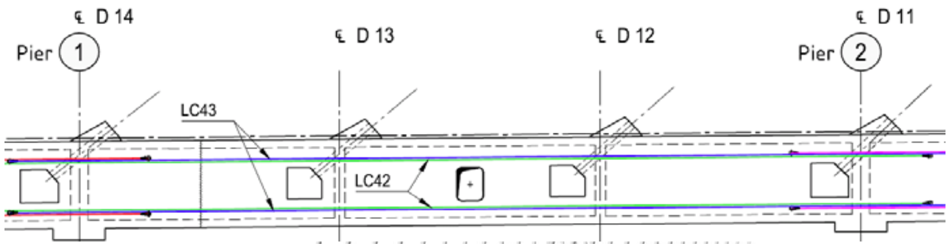
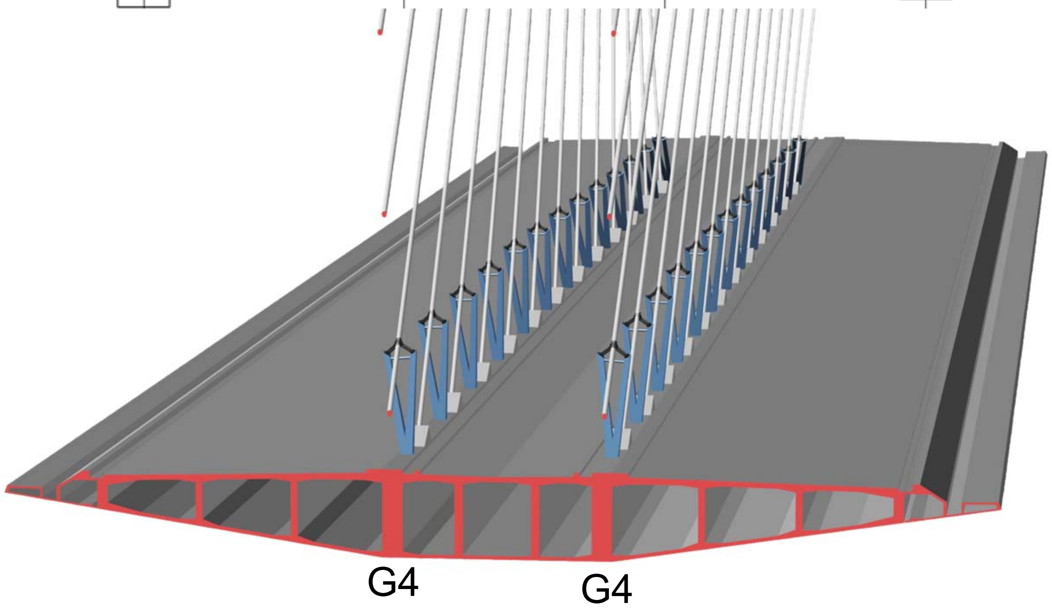


SIDE SPAN





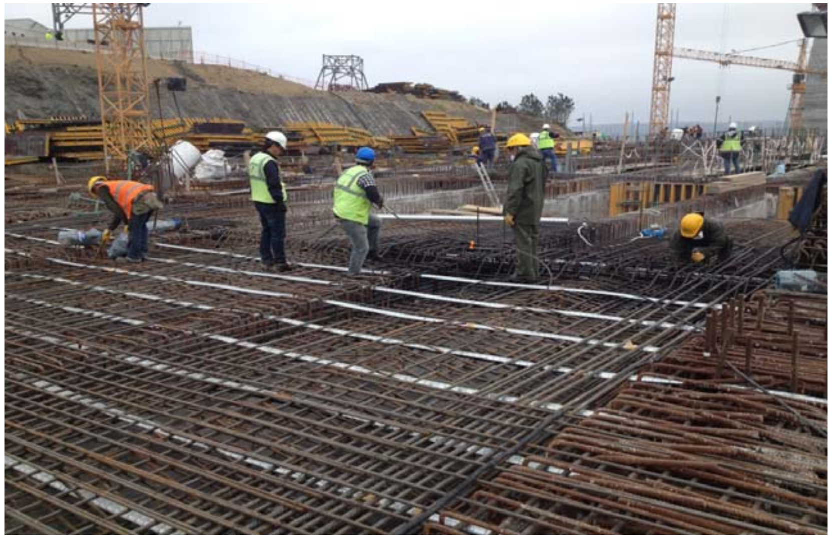


- Axial longitudinal prestressing (more effective avoiding secondary moments)
- Transversal prestressing in diaphragms and top slab. - combination of **internal bonded** and **external unbonded** tendons.

TRI DIMENSIONAL BEHAVIOUR

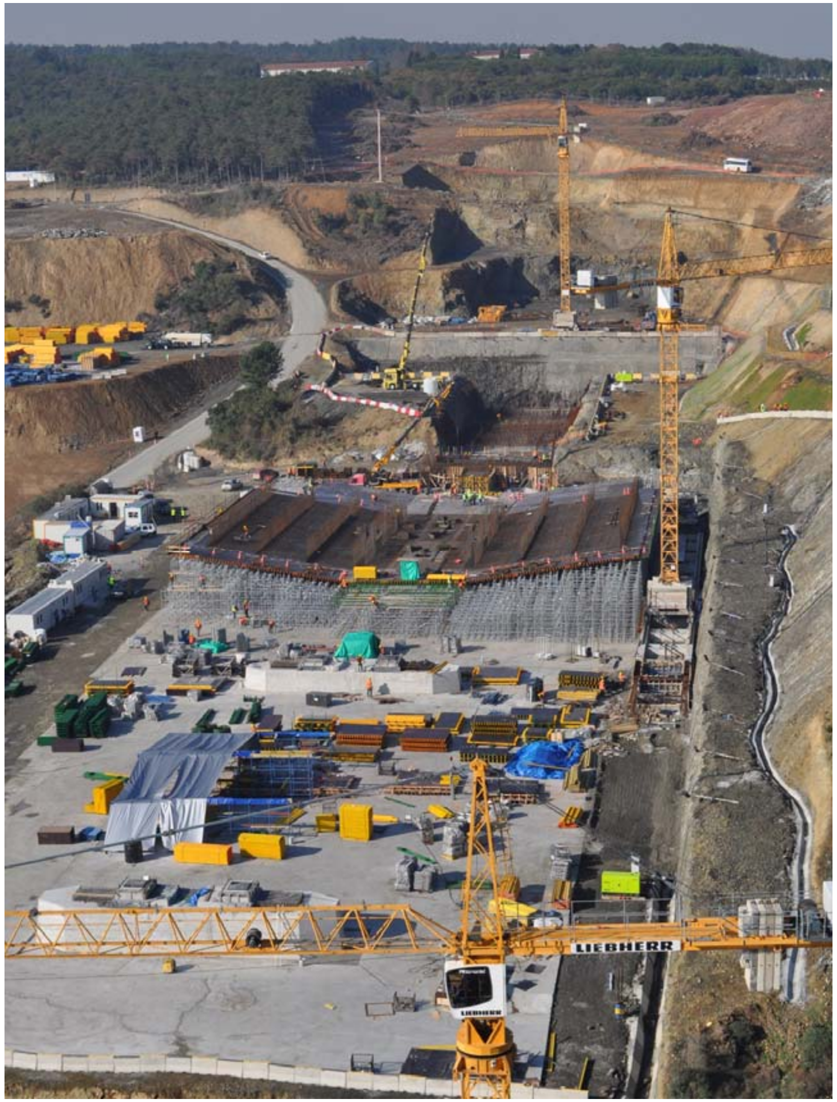
- Multiple cell box girder, 47m wide / 5,3m high
- N.10 Girders (including 2 main girders – G4)
- 21 Transversal Diaphragms (spaced 15m)
- Supports under main girders G4

PROJECT DESCRIPTION



Anchorage block, side Span Piers Works

PROJECT DESCRIPTION



Ground Approach and Side Span Piers Works

PROJECT DESCRIPTION




Ground Approach and Side Span Piers Works

PROJECT DESCRIPTION

PROJECT DESCRIPTION

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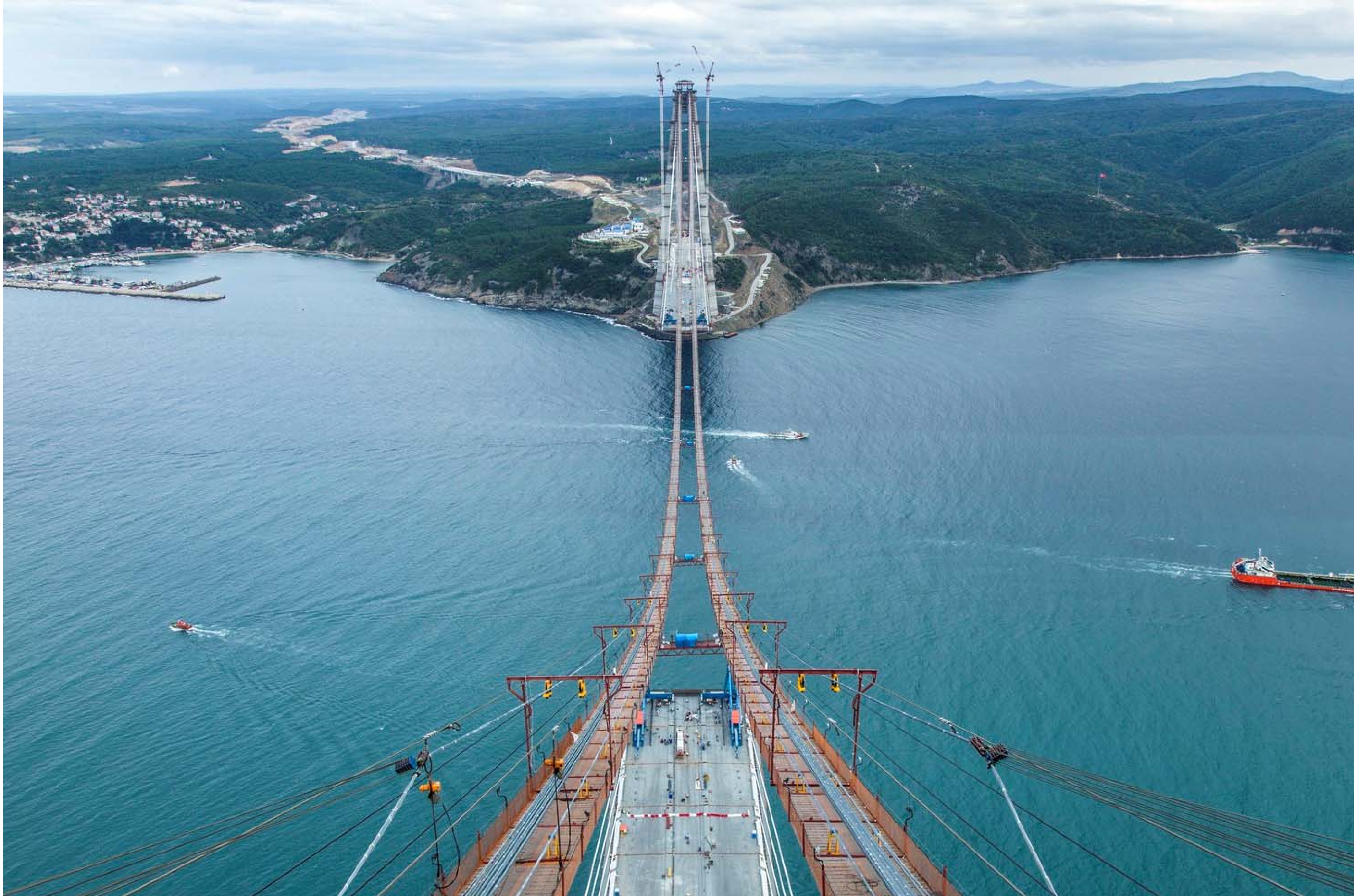
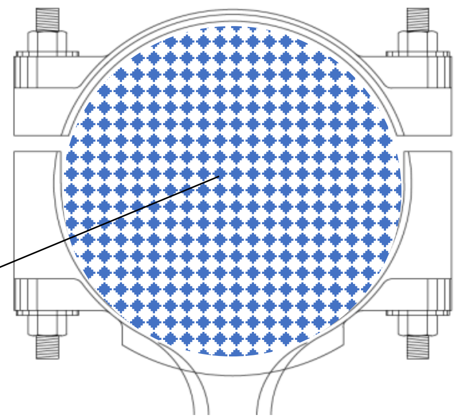


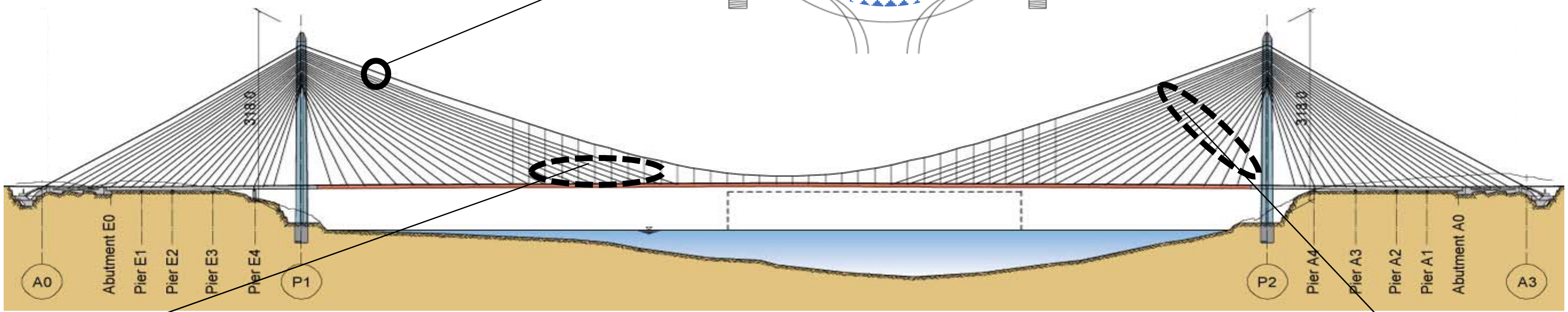
❖ Cable System

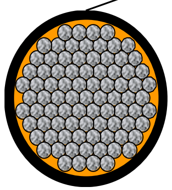
CABLE SYSTEM

22.000 t CABLES

MAIN CABLE (PPWS) 1.860 Mpa	
Lunghezza in asse	4.842 m (2x2.421 m)
Diametro	723-753 mm

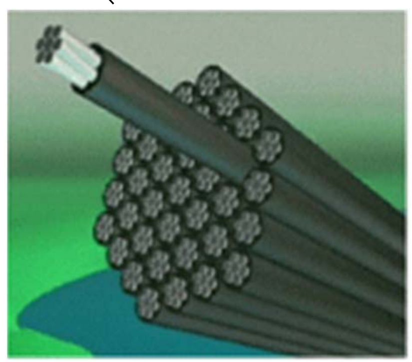






HANGERS (PWS) 1,760 MPa	
Quantita'	68 pezzi
Lunghezza	13 – 106 m
Diametro	100 – 175 mm

STIFFENING CABLES (PSS) 1.960 MPa	
Quantita'	176 pezzi
Lunghezza	154 – 597 m
Diametro	225 – 315 mm



ASTALDI

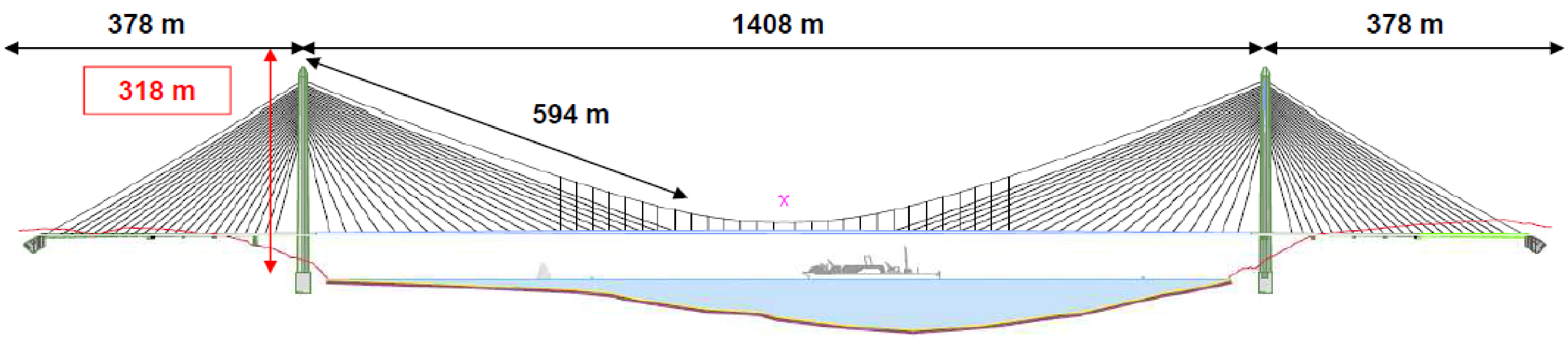
STIFFENING CABLES

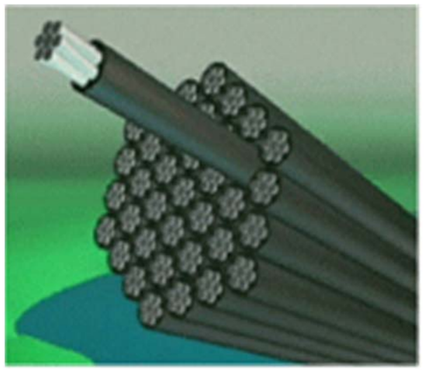
This principle has many advantages, including:

- installation and tensioning of each strand individually;
- individual protection against corrosion;
- individual removal and replacement if necessary.

PSS **(Parallel Strand System) 1.960 Mpa**

Diameter	280-315 mm
Total number	22 x 4 x 2 = 176
Total weight	8.816 t





176 CABLES

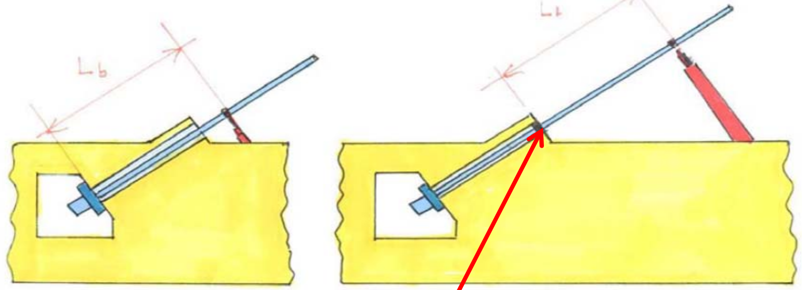
65-151 N. STRANDS PER CABLE

7 WIRES PER STRAND (wire diam. 5.4 mm)

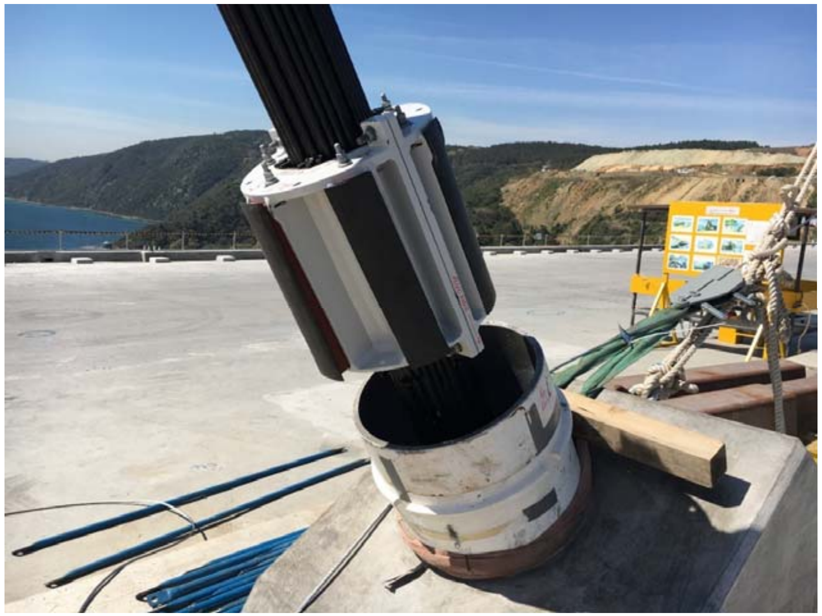
ASTALDI

STIFFENING CABLES

DAMPING SYSTEM - BACK SPAN



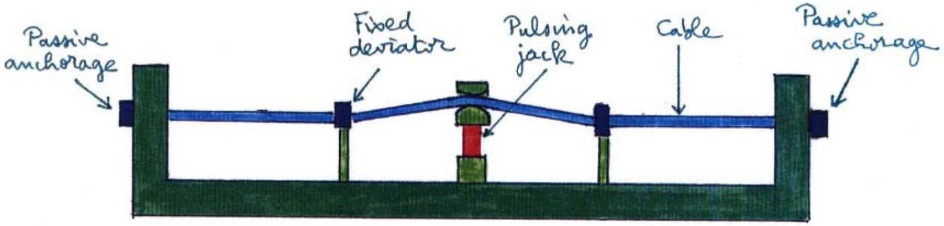
THE NECESSITY TO USE **DEVIATORS** FOR STRUCTURAL SAFETY AND DURABILITY

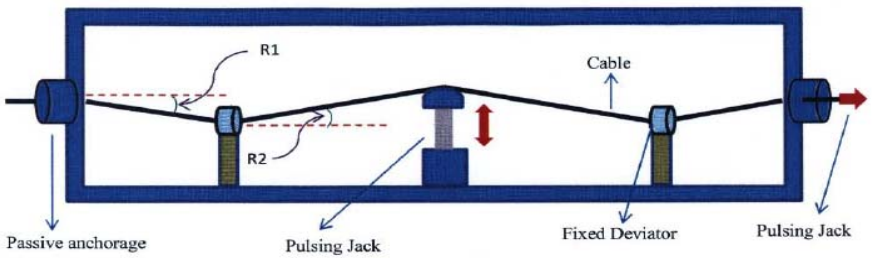


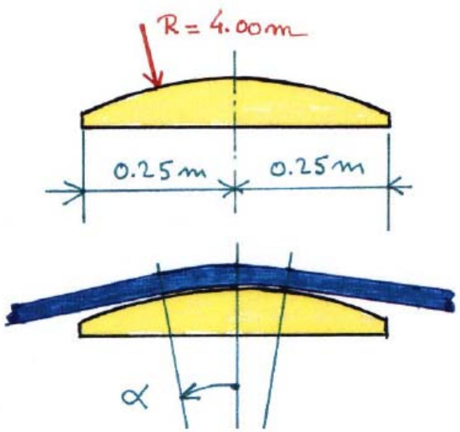
STIFFENING CABLES

Deviator test

		Fatigue test				
No strands	GUTS (kN)	Minimum Load (kN)	Maximum load 0.35 GUTS (kN)	Minimum angular deviation (mrad)	Maximum angular deviation (mrad)	2 % allowable wire failures
109	32 046	9 172	11 216	-3	+9	15





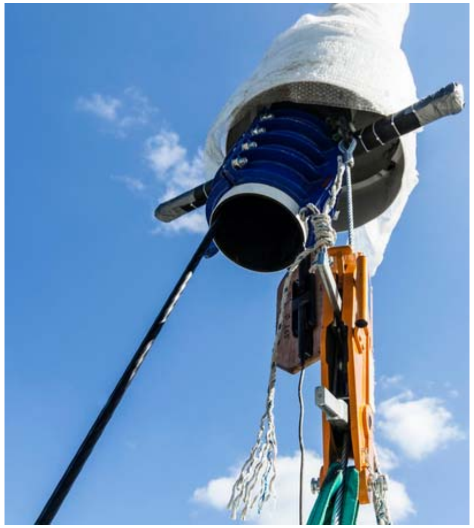


The deviator full scale test is acceptable if:

- No more than 2% of the number of individual wires fail (measured with acoustic monitoring and confirmed by visual inspection).
- Each HDPE strand sheath is still performing as a barrier (visual inspection after the test)
- The structural integrity of the deviator has been ensured (visual inspection after the test)

STIFFENING CABLES

FIRST STIFFENING CABLES INSTALLED (PSS)



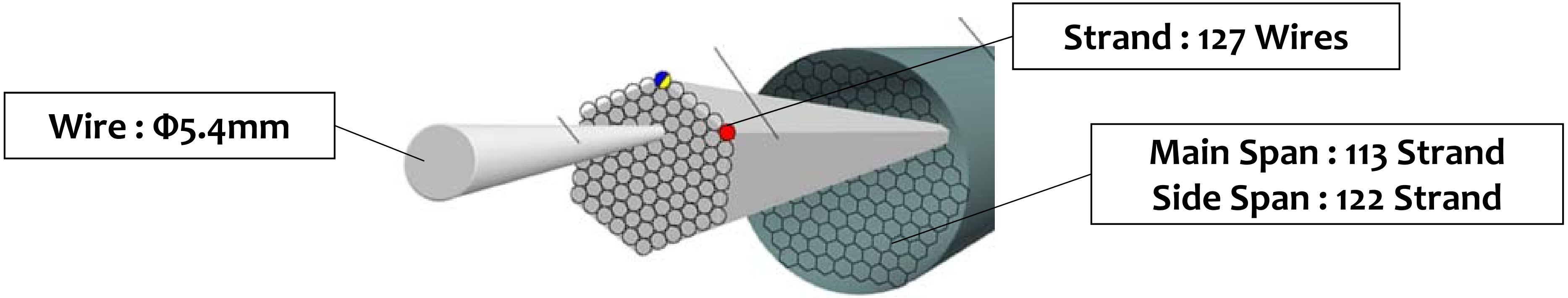
EMPTY DUCTS IN WHICH THE STRANDS ARE INSERTED FROM THE BOTTOM TO THE TOP.

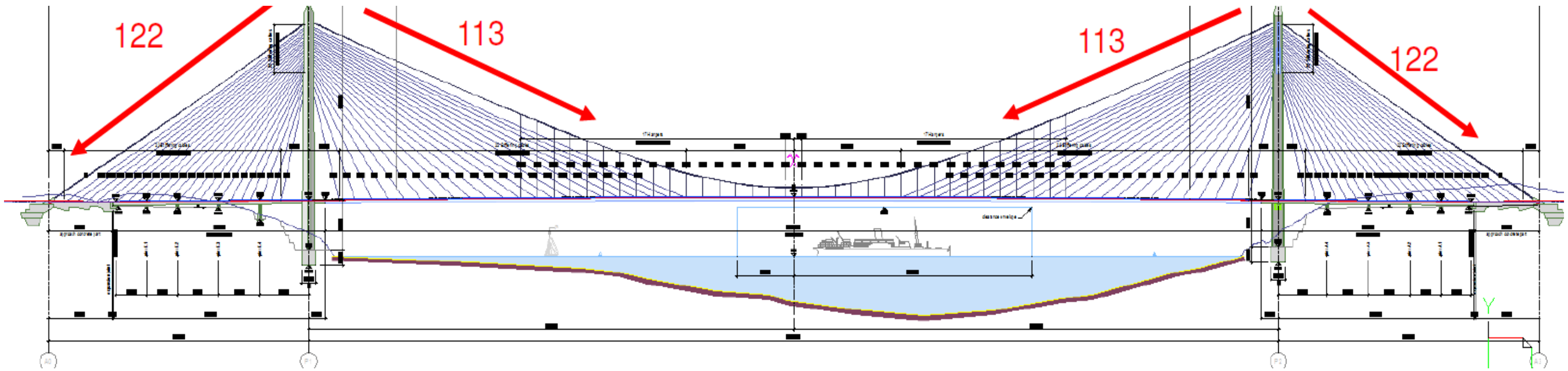
MAIN CABLE

Lenght	4.842 m
Diameter (main and side span)	723 mm – 752 mm
Total weight of main cable	12,822 t

PPWS (Prefabricated Parallel Wire System)

Strenght grade	fuk 1.860 Mpa





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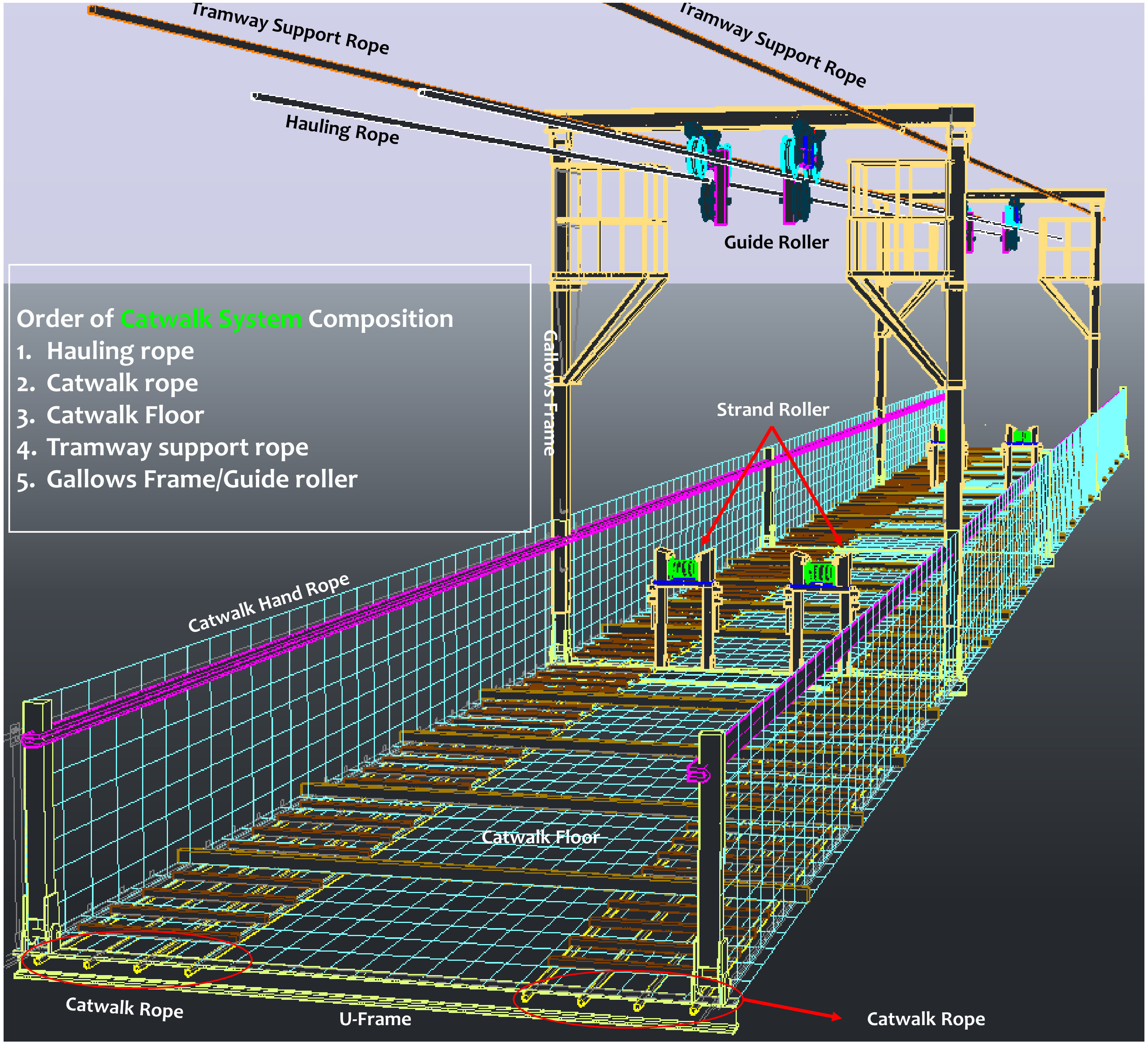
MAIN CABLE

CATWALK SYSTEM INSTALLED FOR THE CONSTRUCTION OF THE MAIN CABLES.



ASTALDI

MAIN CABLE

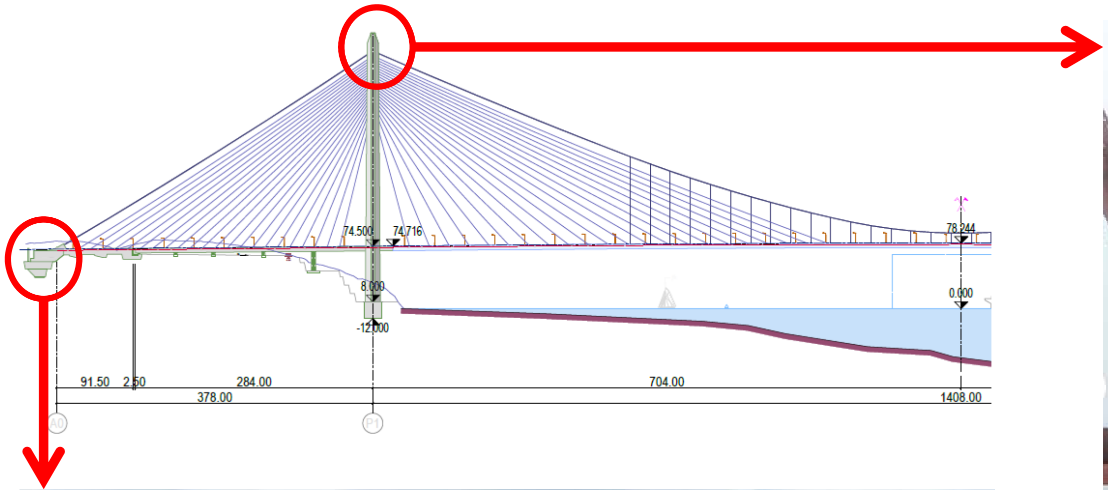
FIRST HAULING CABLE SEA-CROSSING HAS BEEN DONE ON APRIL 13th
BY TWO BARGES APPROACHING EACH OTHER FROM THE TWO CONTINENTS

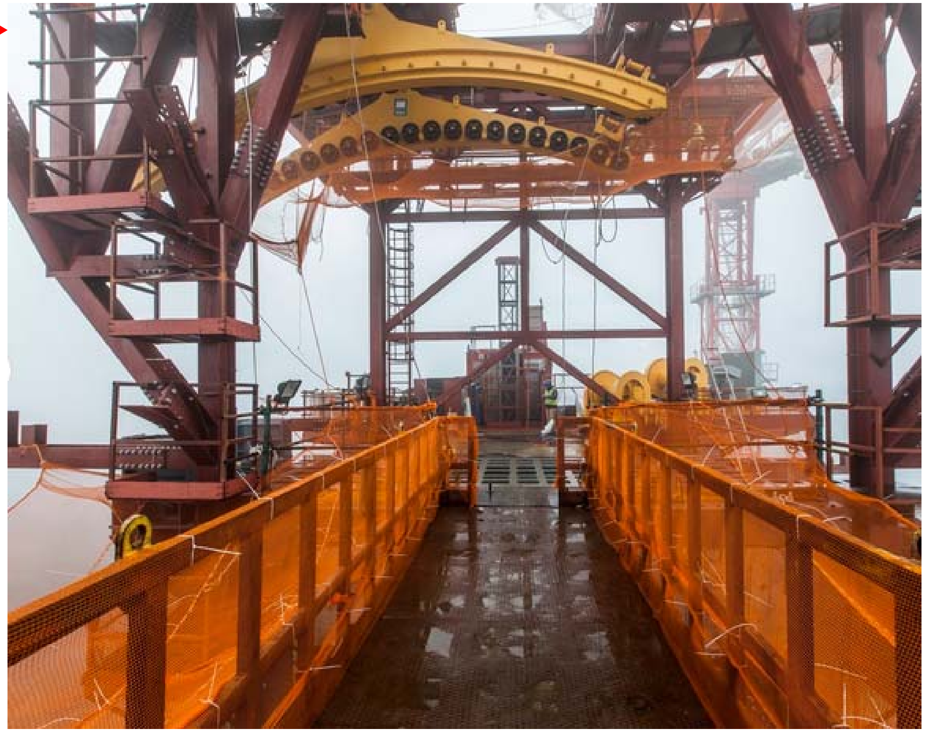
MAIN CABLE

GOLDEN GATE BRIDGE (San Francisco - 1935)

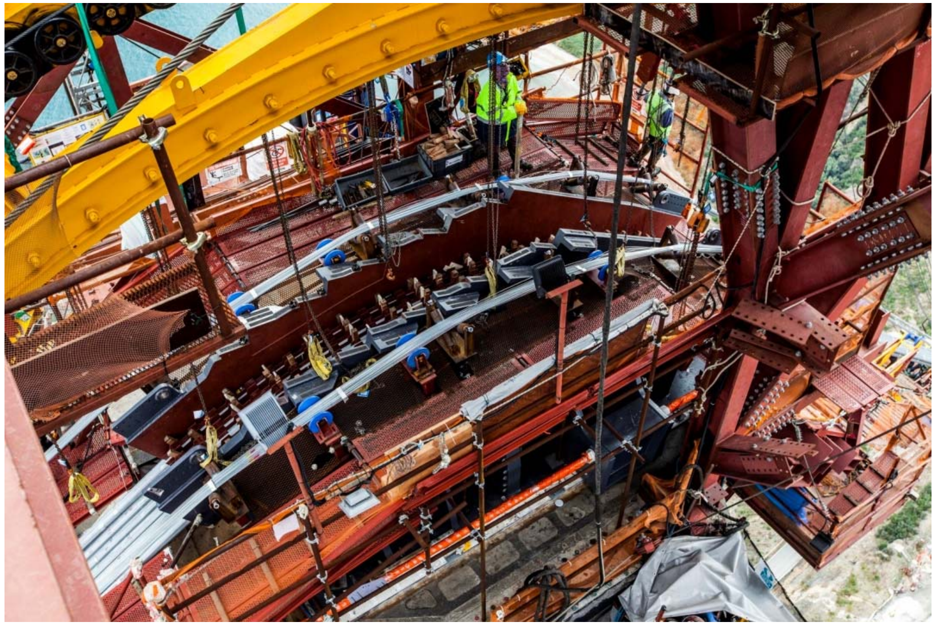
MAIN CABLE

Temporary structures





MAIN CABLE

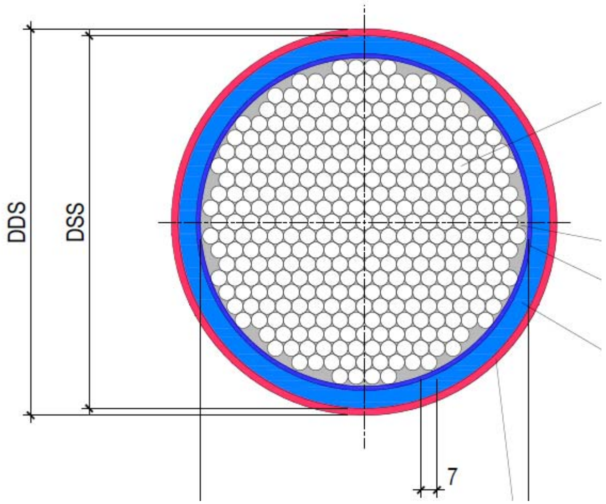


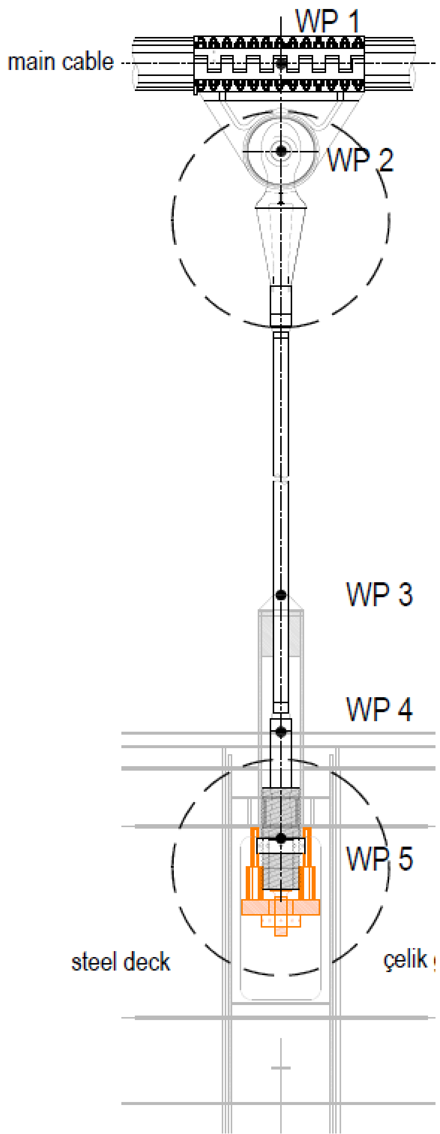
HANGERS

Number of hangers	68
Single wire diameter	7 mm
N. wires each hanger	109 - 367
Single hanger diameter (mm)	100 - 170
Total weight	171 t
Total length of wire	124.832 km

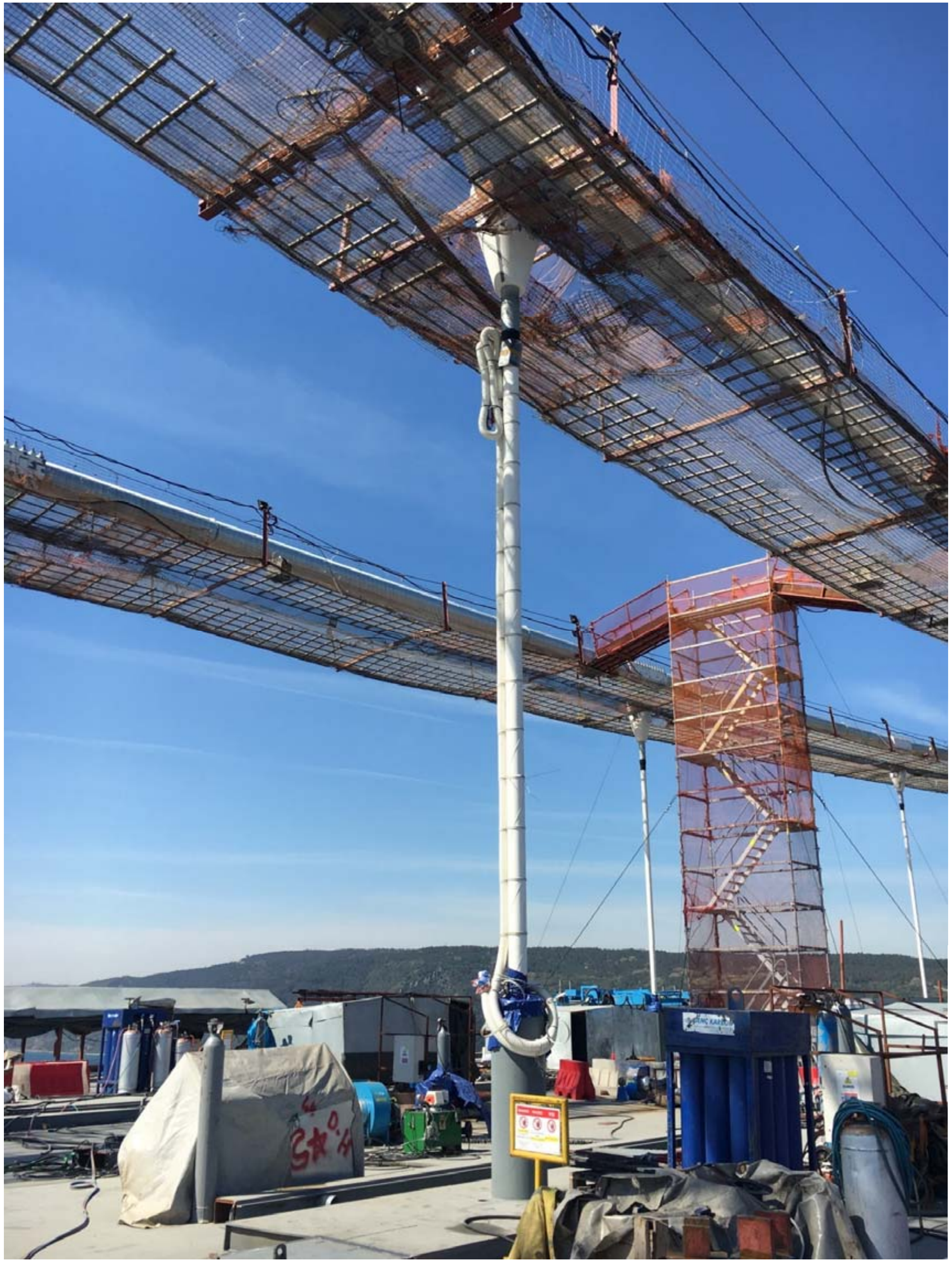
Strenght grade	fuk	1.770 Mpa	/ ø 7

- ANTICORROSION COMPOUND
- WRAPPING TAPE
- BLACK PE SHEALTHS





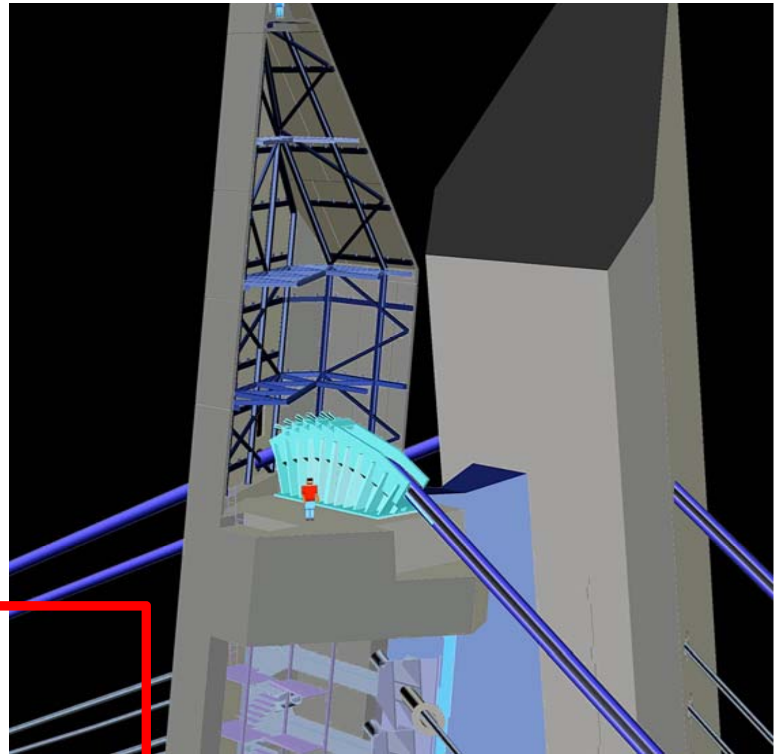
HANGERS



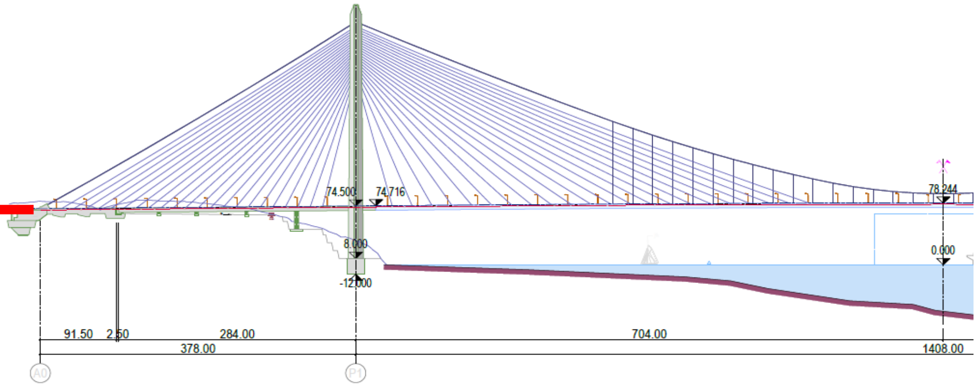
❖ Special devices

SADDLES

N. 4 TOWER SADDLES



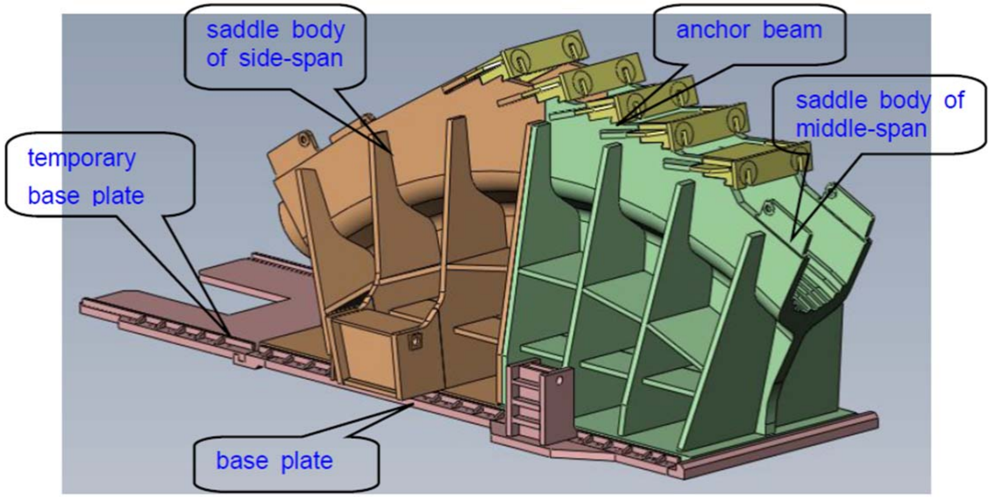
N. 4 SPLAY SADDLES



ASTALDI

TOWER SADDLES

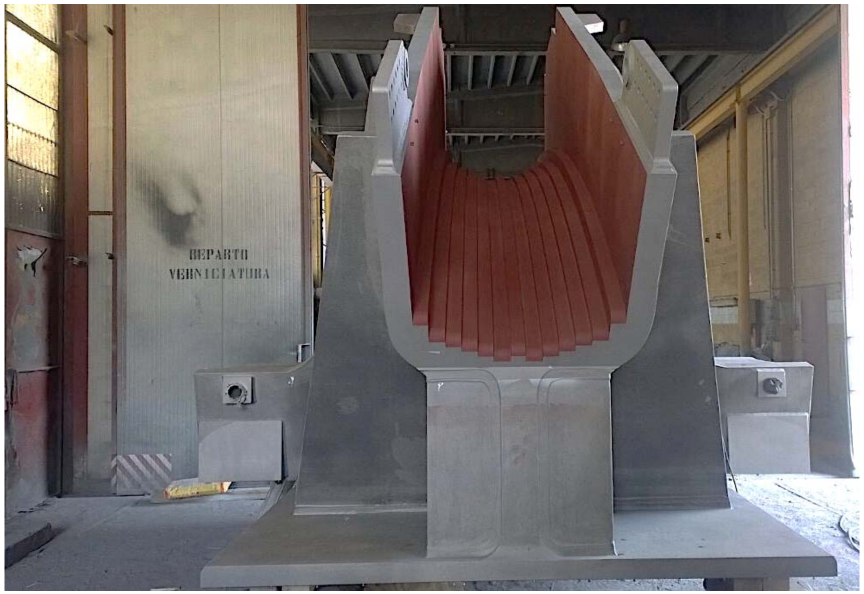
ACCIAIERIA FONDERIA CIVIDALE S.p.A.
LINGOTTI E GETTI IN ACCIAIO



Three-dimensional stereogram of tower saddle

Total weight: 92 ton

Height 307 cm
Width 250 cm
Length 680 cm



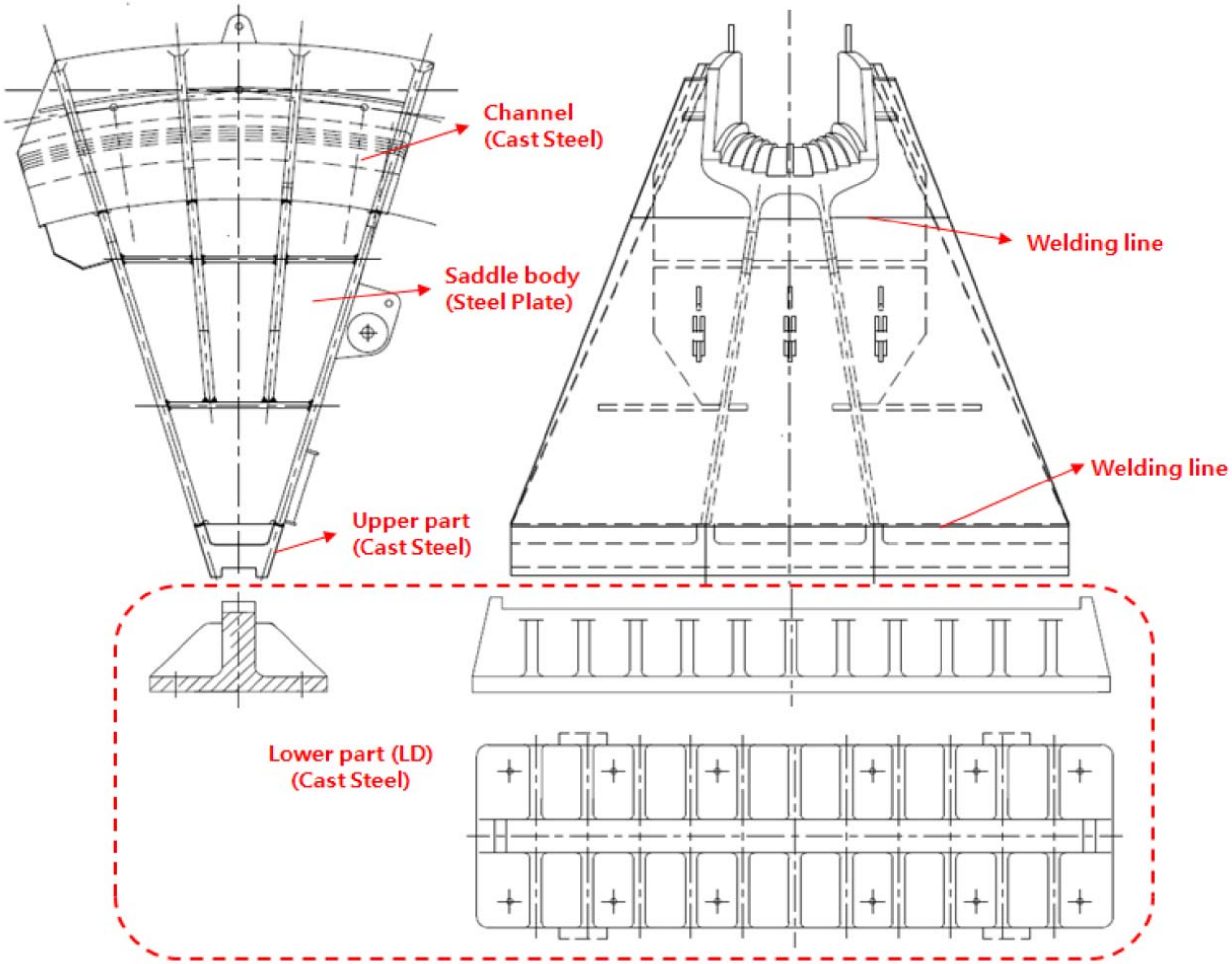
ASTALDI

TOWER SADDLES

SPLAY SADDLES

Composed by 4 parts:

- Lower part
- Upper part
- Saddle body
- Channel



[Splay Saddle (SS)]

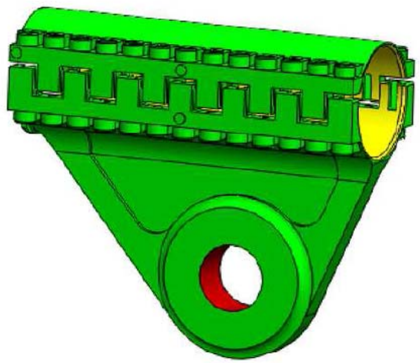
ASTALDI

SPLAY SADDLES

Total weight: 79 ton

Height 507 cm
Width 490 cm
Length 358 cm

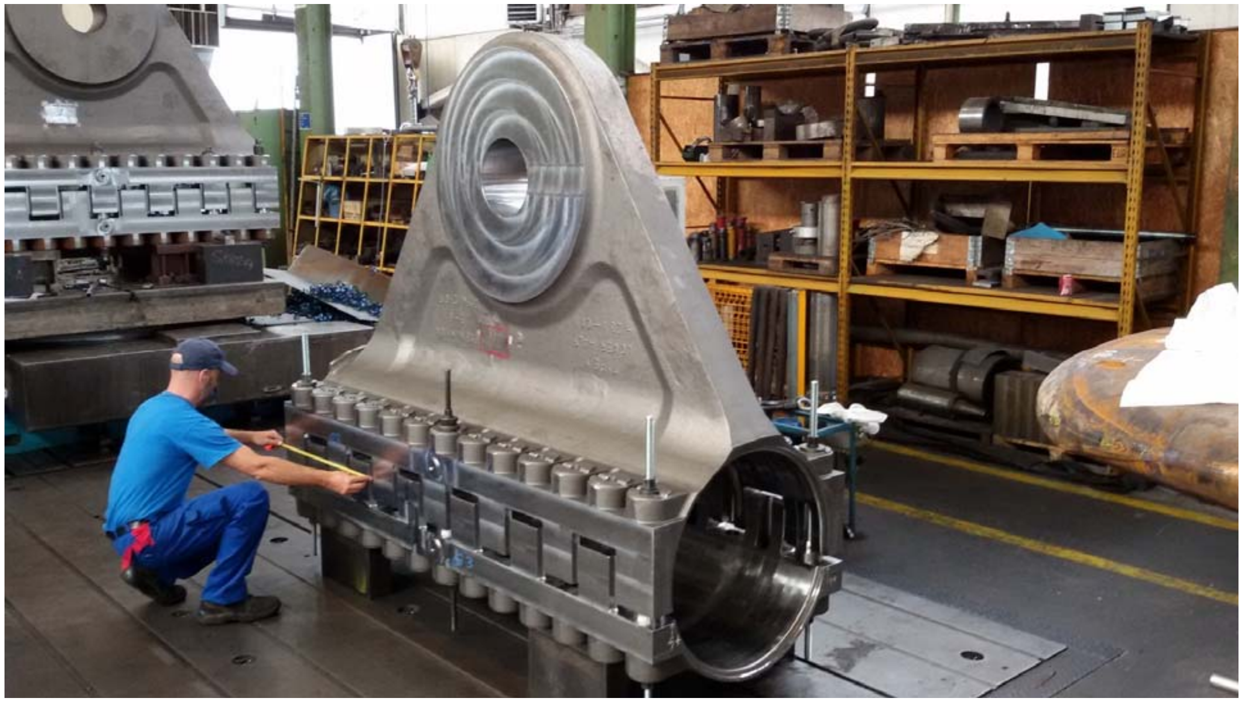
CABLE BANDS



Type 1

Total 188 pieces
Total weight of all 335,5 t

Length var. from 36 to 234 cm



ASTALDI

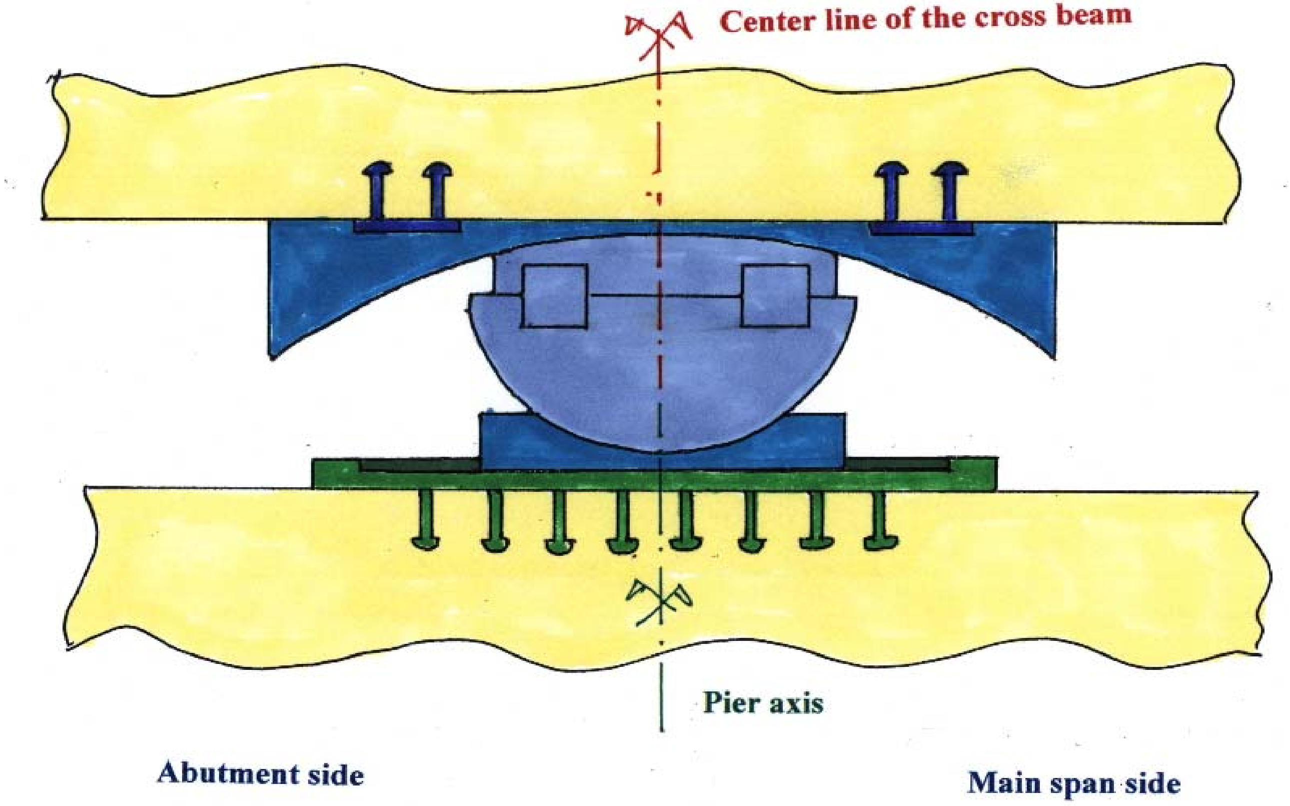
PENDULAR BEARINGS

Pendular bearings have been chosen in order to control longitudinal displacements and seismic behaviour.

They are installed on all supports, except abutments, to reduce longitudinal displacements by both friction and pendular effect.

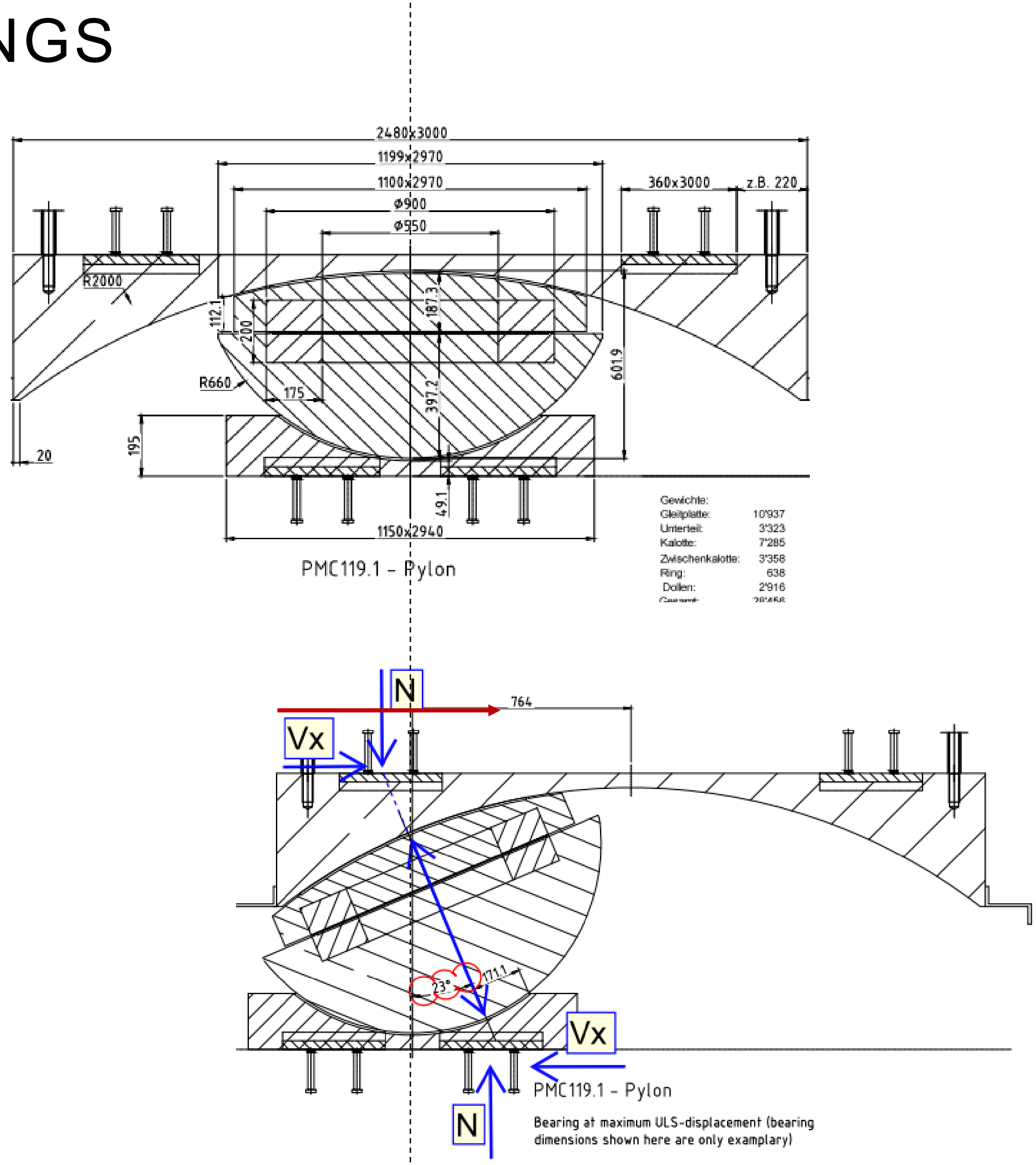
The design of the vertical radius optimised the following 4 effects:

- Temperature effects
- Train stopping on the bridge
- Dynamic train
- Earthquake



ASTALDI

PENDULAR BEARINGS

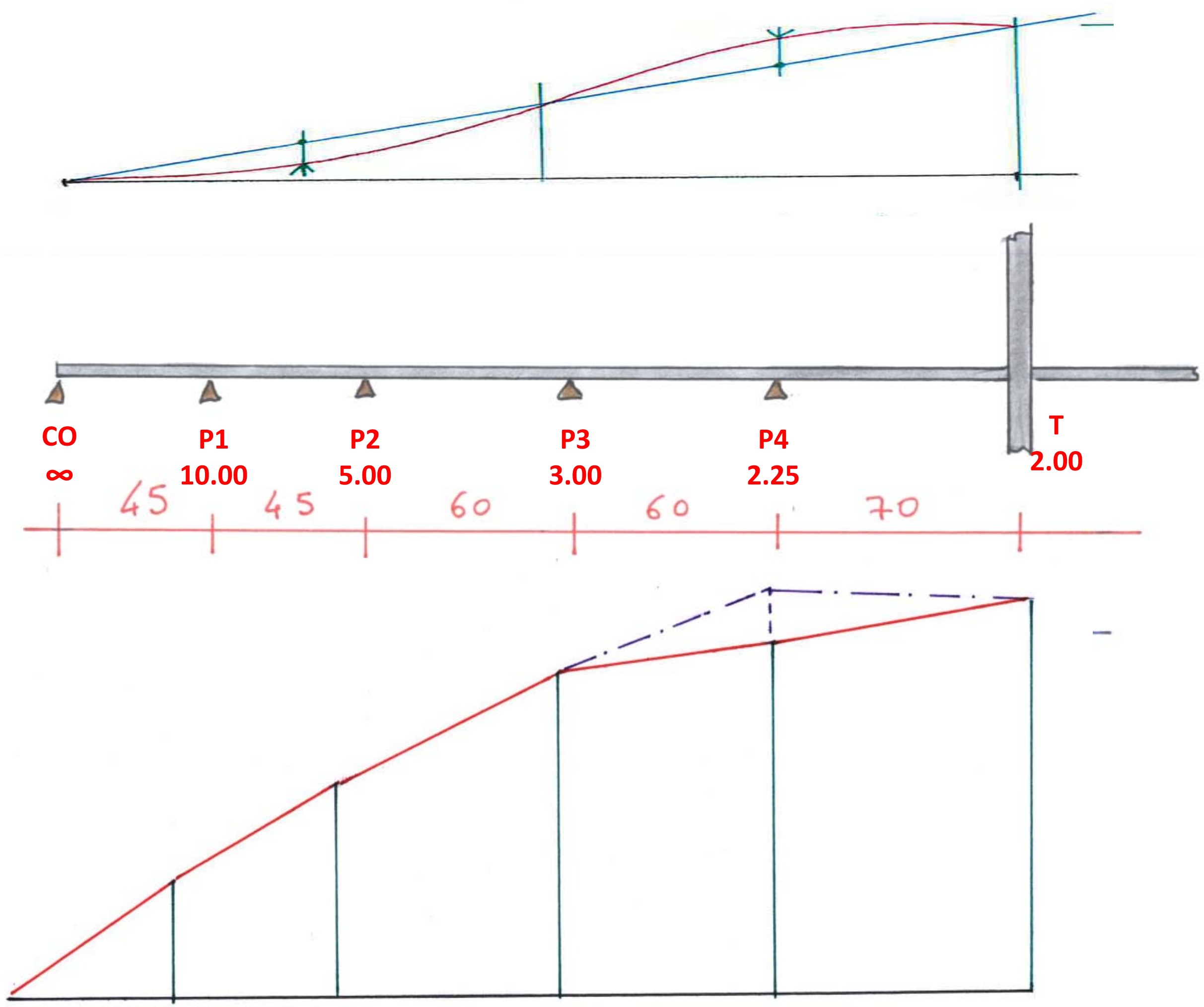


Longitudinal displacement

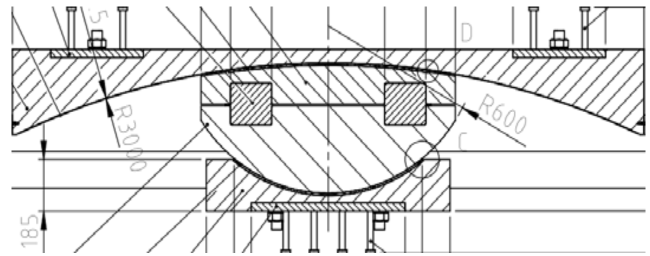
⇒ longitudinal reaction force

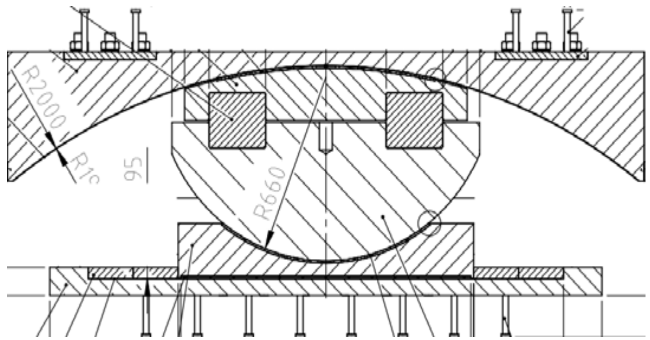
⇒ Stiffening the global system

PENDULAR BEARINGS



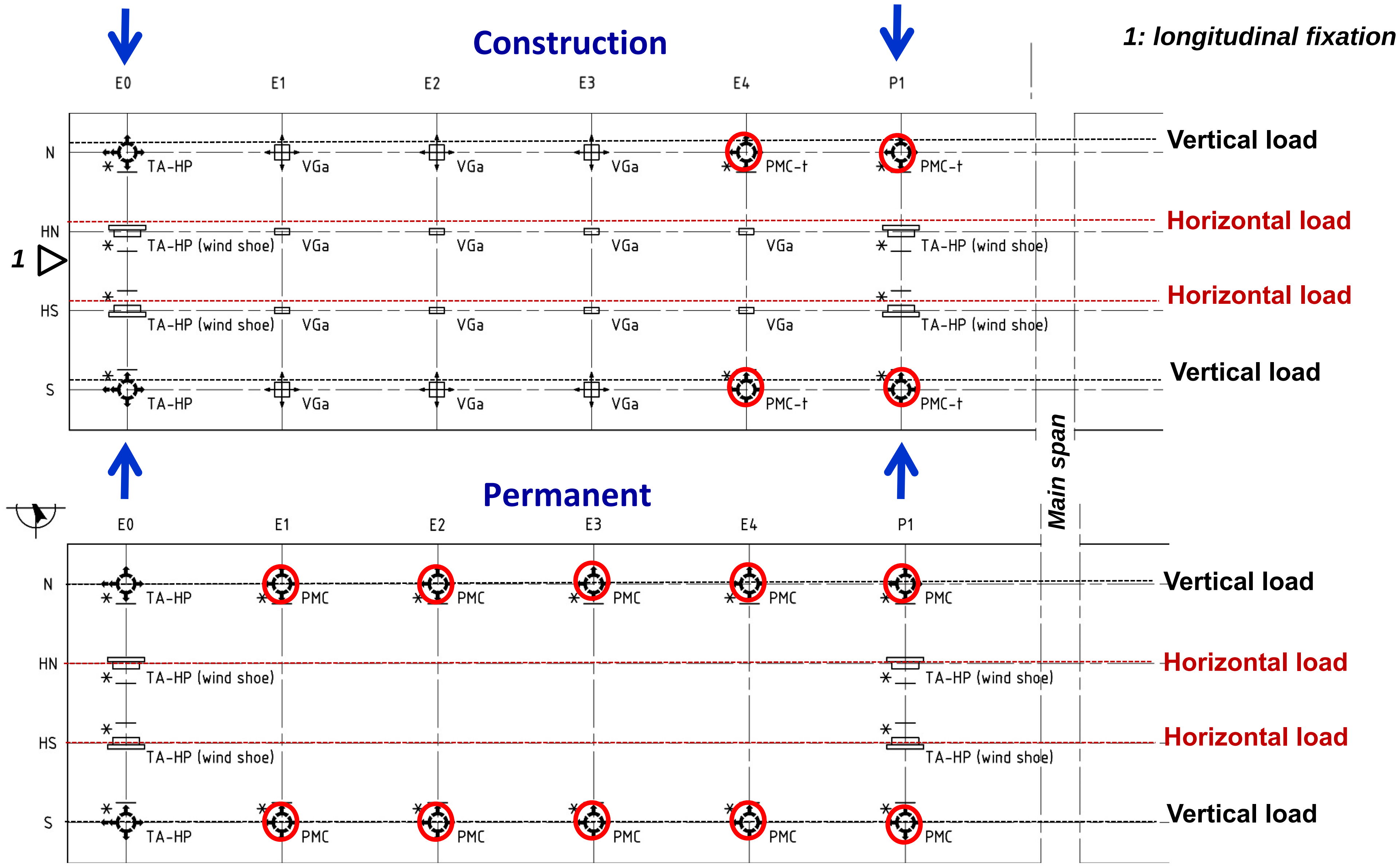
i	R_i (m)
C0	∞
P1	10.00
P2	5.00
P3	3.00
P4	2.25
Tower	2.00



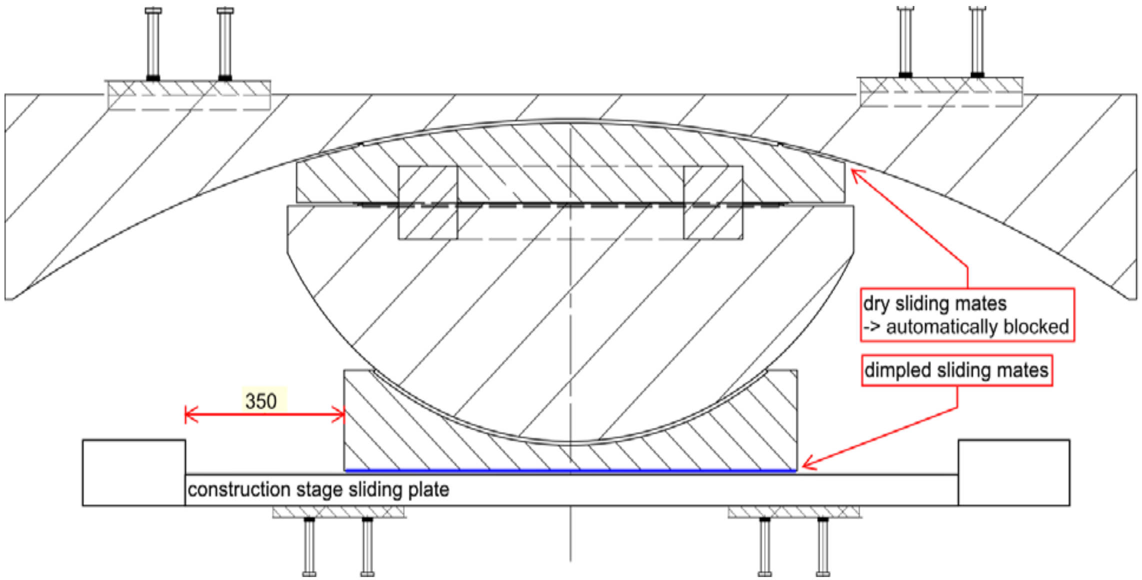


The curvature radii of pendular bearings have been selected to produce a progressive vertical displacement on supports

PENDULAR BEARINGS

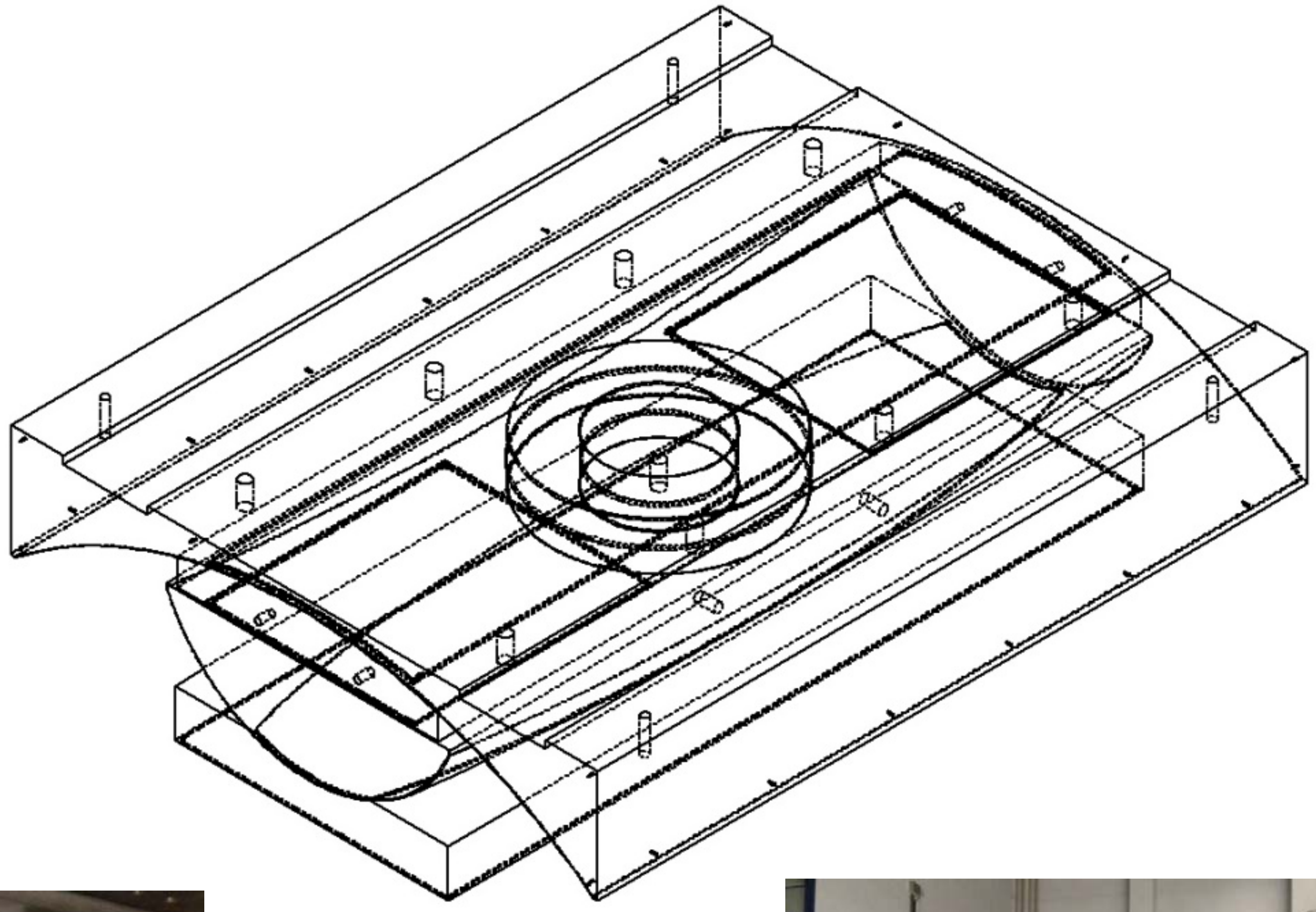


PENDULAR BEARINGS



PENDULAR

Isometry



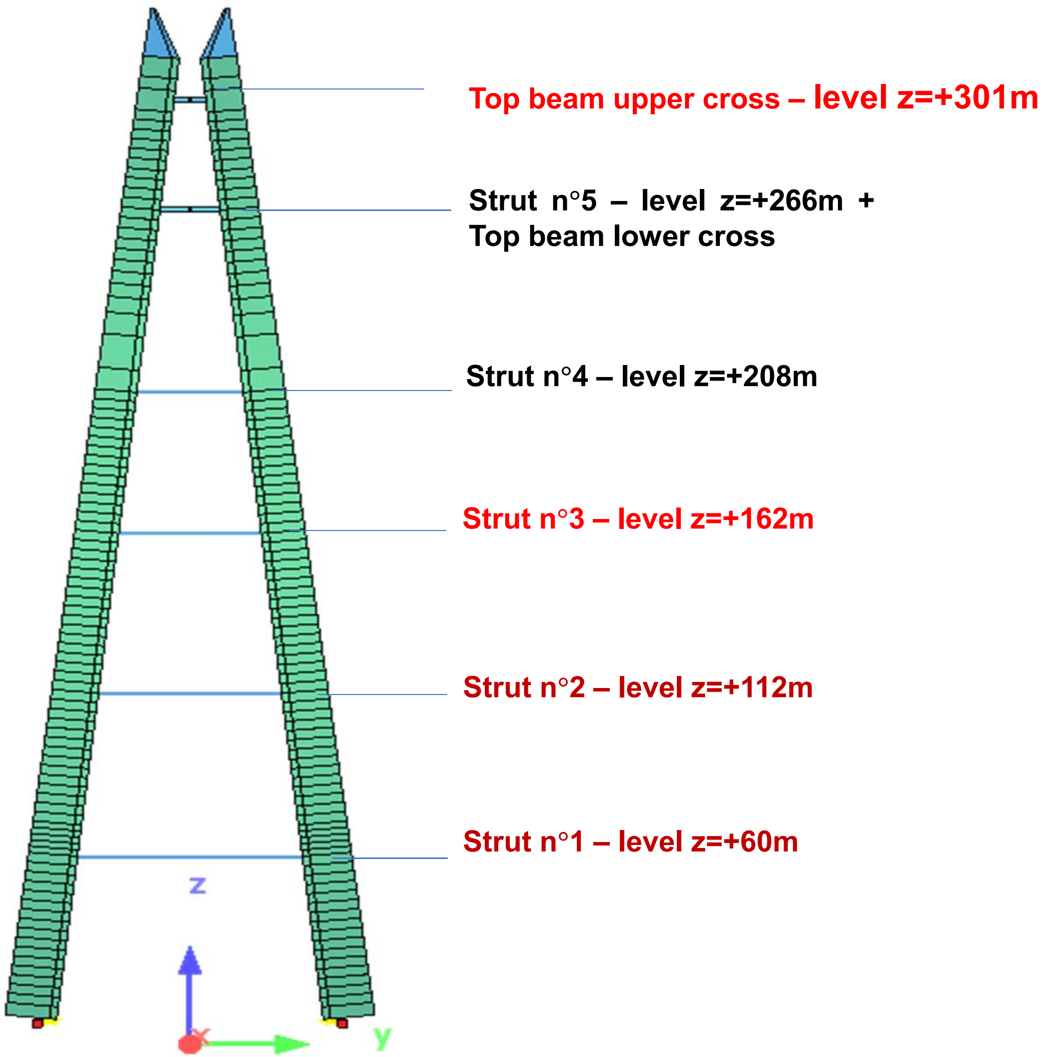
Fatigue test in Eucentre in Pavia

ASTALDI

❖ **Pylons**

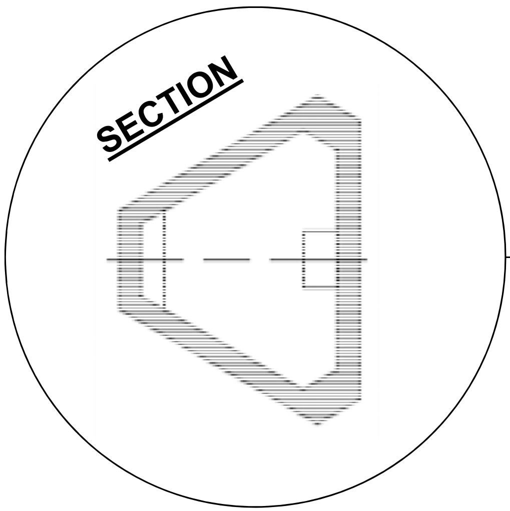
TOWERS

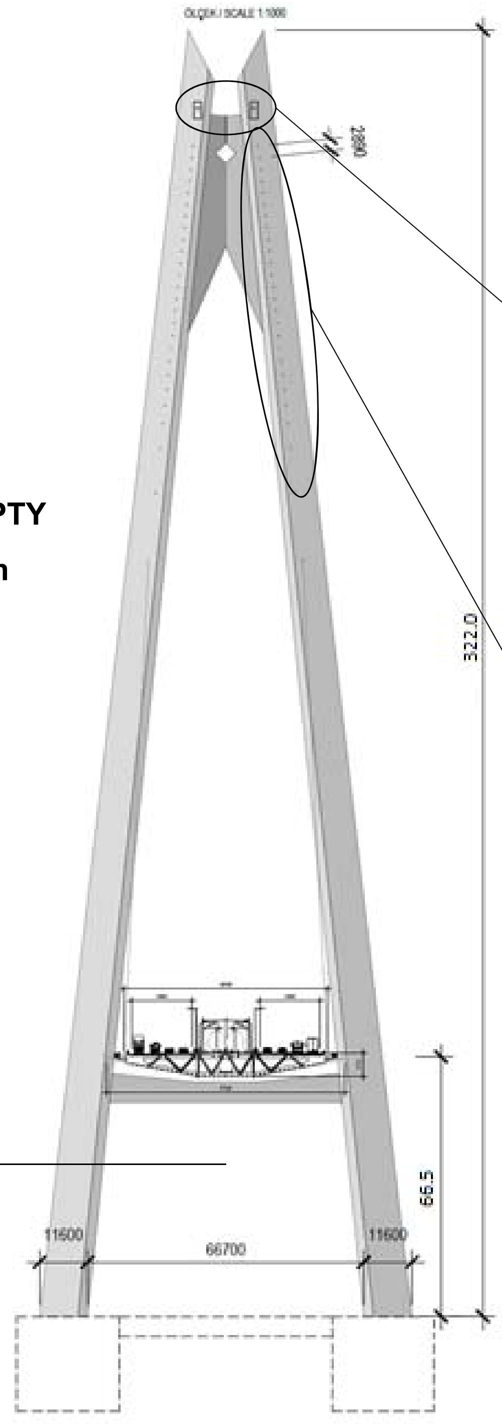
ERECTION SEQUENCE



TOWERS

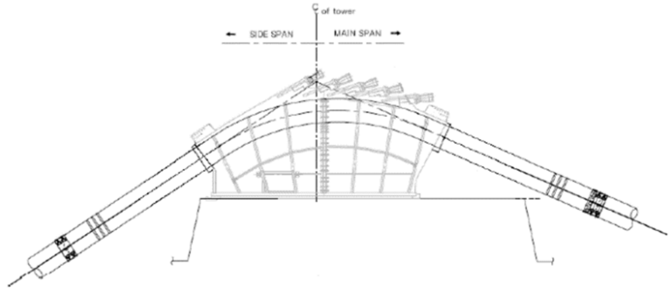
- **TOTAL HEIGHT = 322,0 m**
- **TOTAL CONCRETE HEIGHT = 305,0 m**
- **INCLINATION 6 DEGREES**
- **BASE DISTANCE 66,7 m**
- **INTERNAL SECTION TRIANGULAR – EMPTY**
- **TICKNESS VARAIBLE FORM 1,5 TO 0,75m**



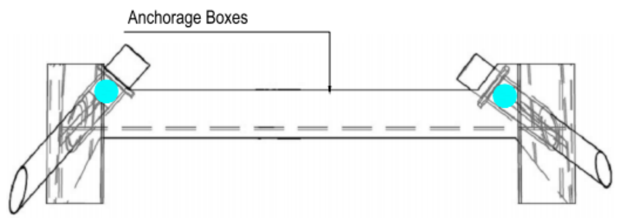


The towers have been designed in order to support the loads coming from the two cable systems.

The two main cables give the loads through the Tower Saddles.



The stay cables are anchored with anchor boxes poured in the concrete of the towers.



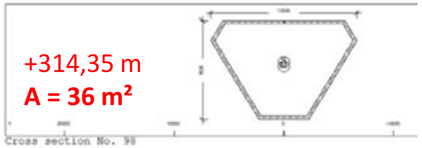
MATERIAL UTILISED

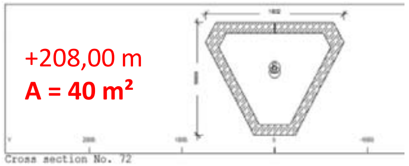
Concrete dispositions

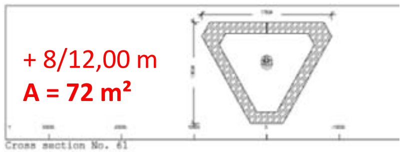
DESIGNATION	Strenght class	Exposure class	Concrete cover (min.)
Tower's leg (splash zone, up to 30 m)	C50/60	XS3 XC4	50mm
Tower's leg and concrete crossbeam	C50/60	XS1 XC4	40mm

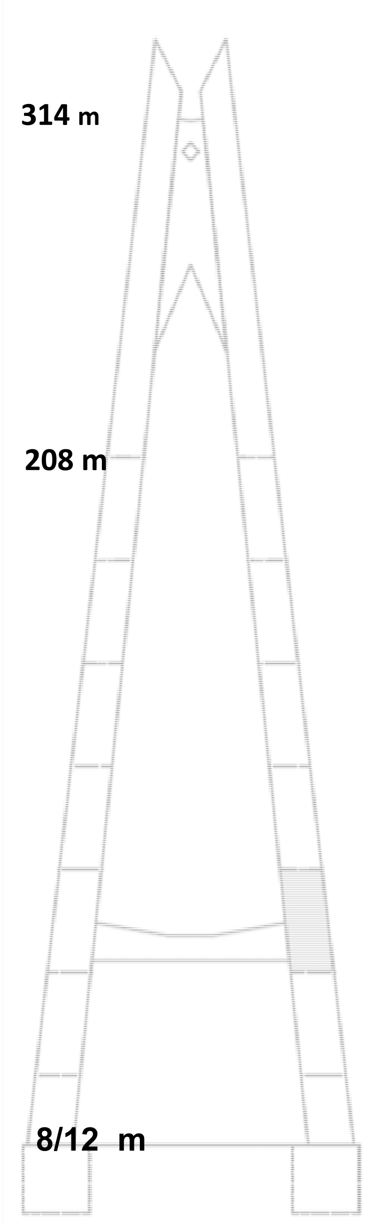
Rebar B500B connected with couplers

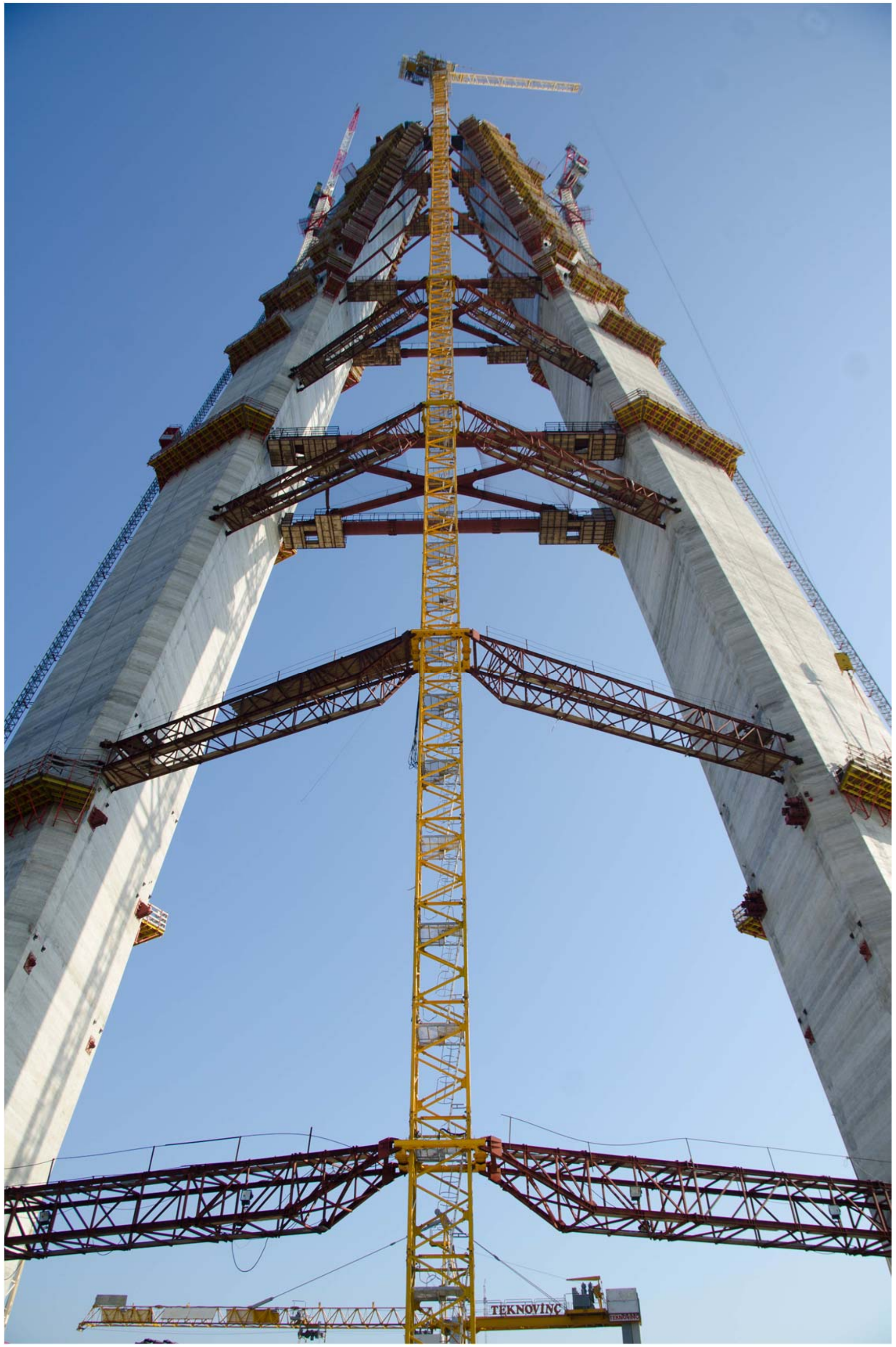
TOWERS


+314,35 m
A = 36 m²
Cross section No. 98

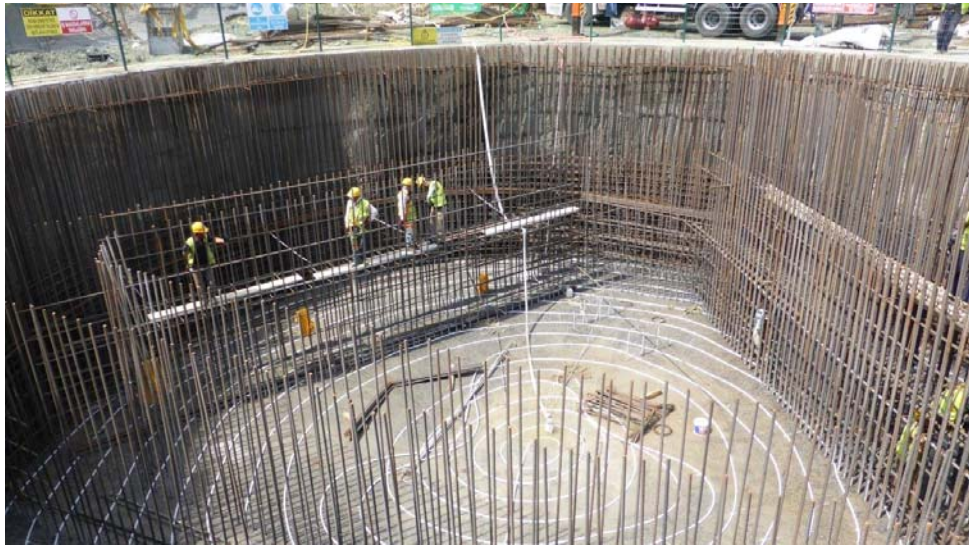

+208,00 m
A = 40 m²
Cross section No. 72

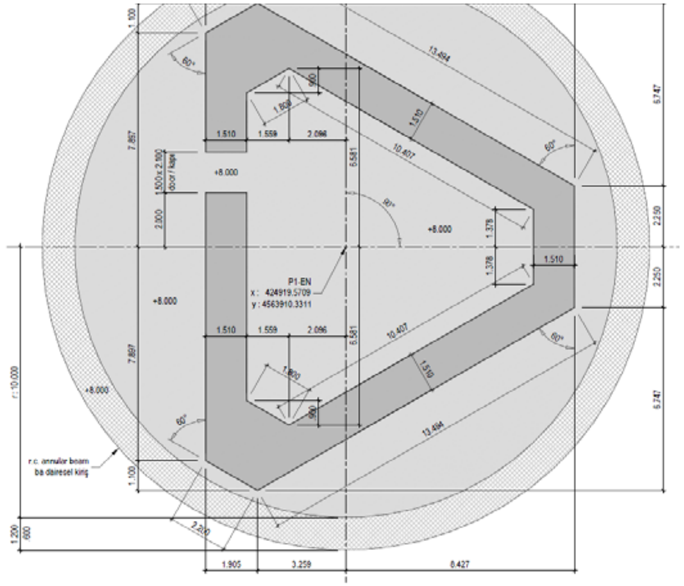

+ 8/12,00 m
A = 72 m²
Cross section No. 61

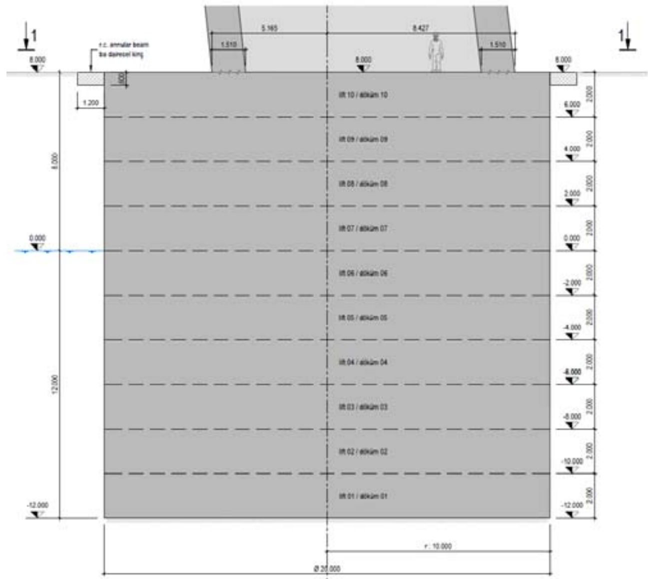

314 m
208 m
8/12 m


TEKNOVINÇ

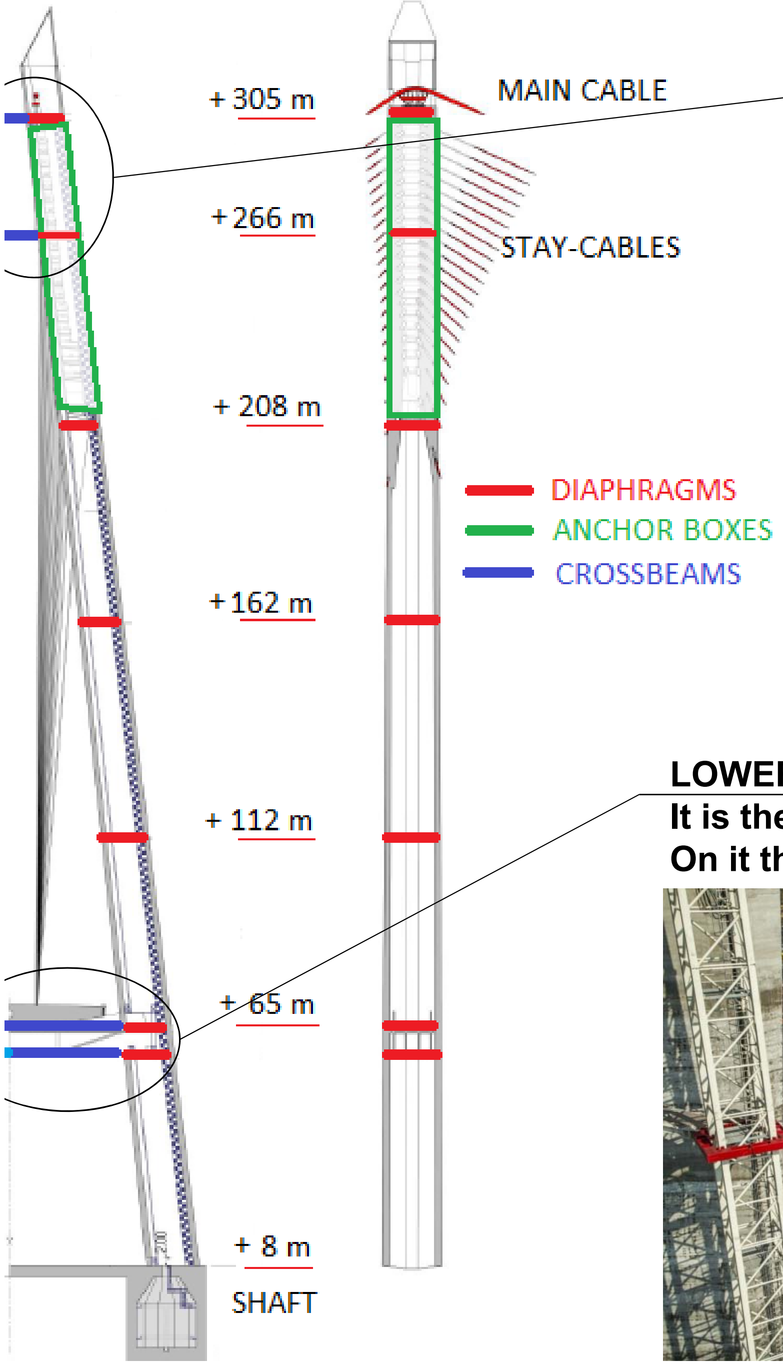
TOWER SHAFTS





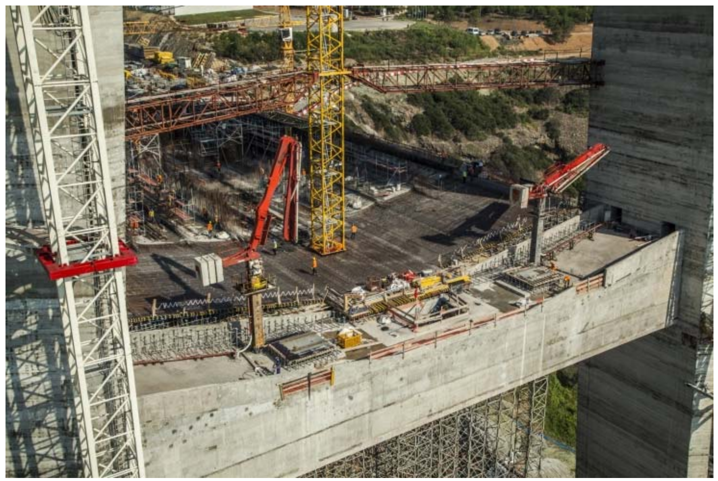


TOWER LOWER CROSS BEAM



UPPER 2 CROSSBEAM: **Steel X-bracings, subsequently covered with steel pannels welded**

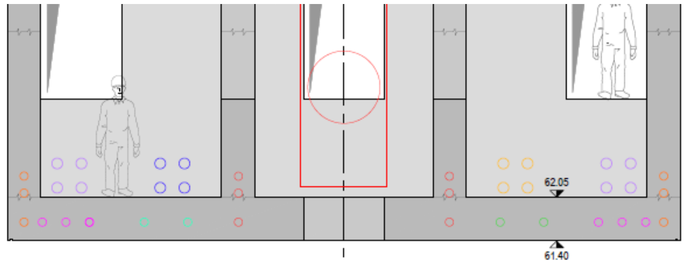
LOWER CROSSBEAM: Concrete structure post tensioned.
It is the first structural permanent connection between the two legs of the pylon.
On it the approach concrete deck will lean over.

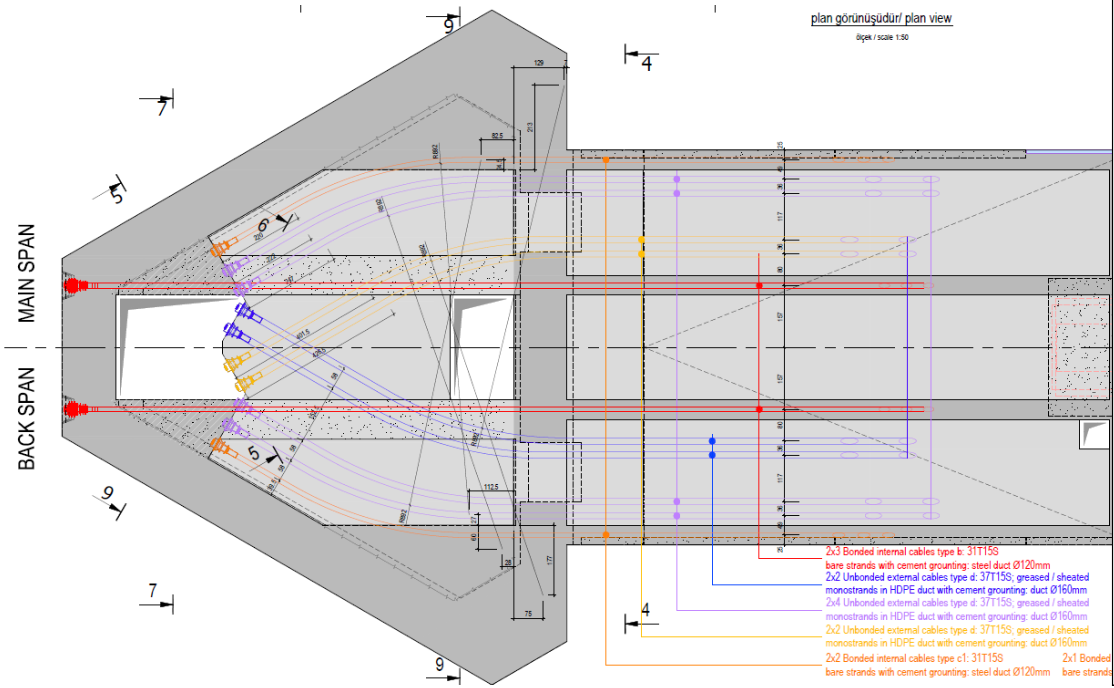


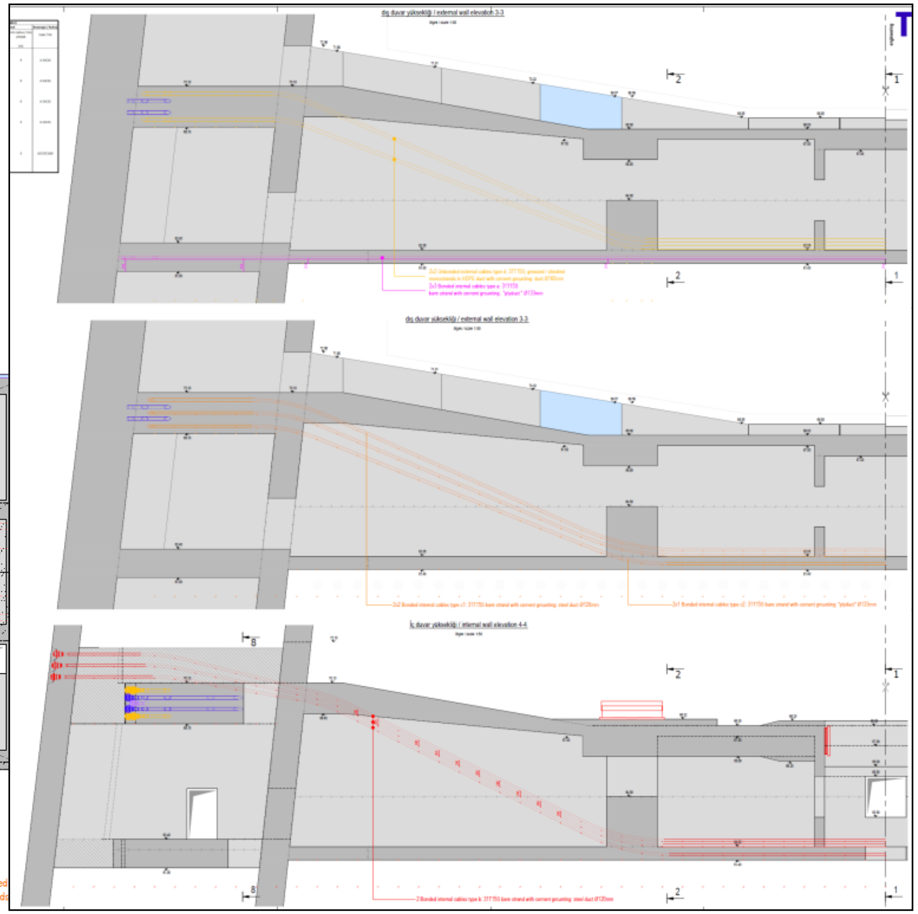
TOWER LOWER CROSS BEAM

38 prestressed cables

- 12 deviated internal cables in webs (31T15S) – steel duct
    - 6 anchored in pylon face and 6 in pylon slab
- 10 straight internal cables in bottom slab (31T15S) – Plyduct
- 16 deviated external cables (37T15S) – HDPE duct

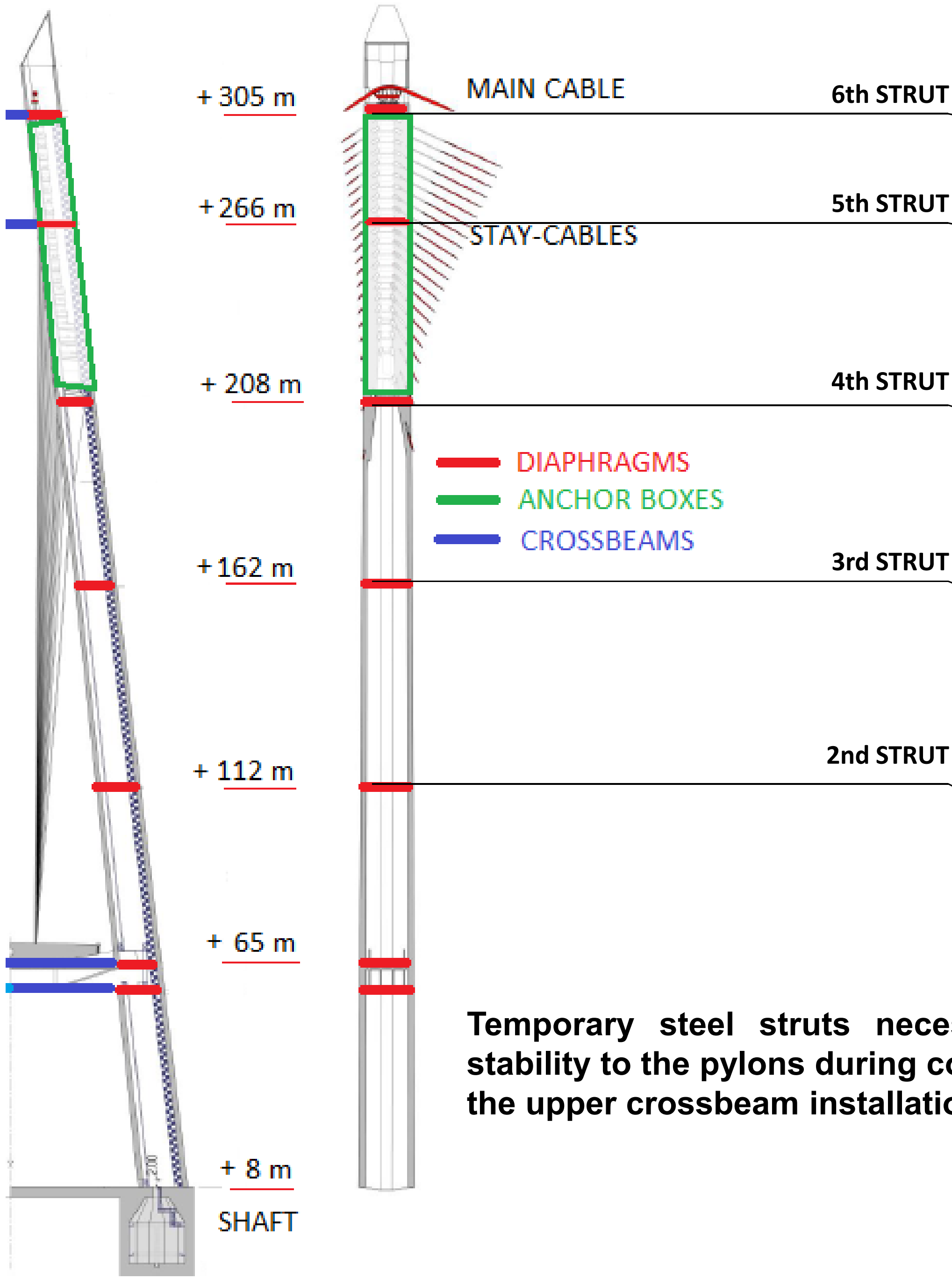






TOWER LOWER CROSS BEAM

TOWERS TEMPORARY STRUTS

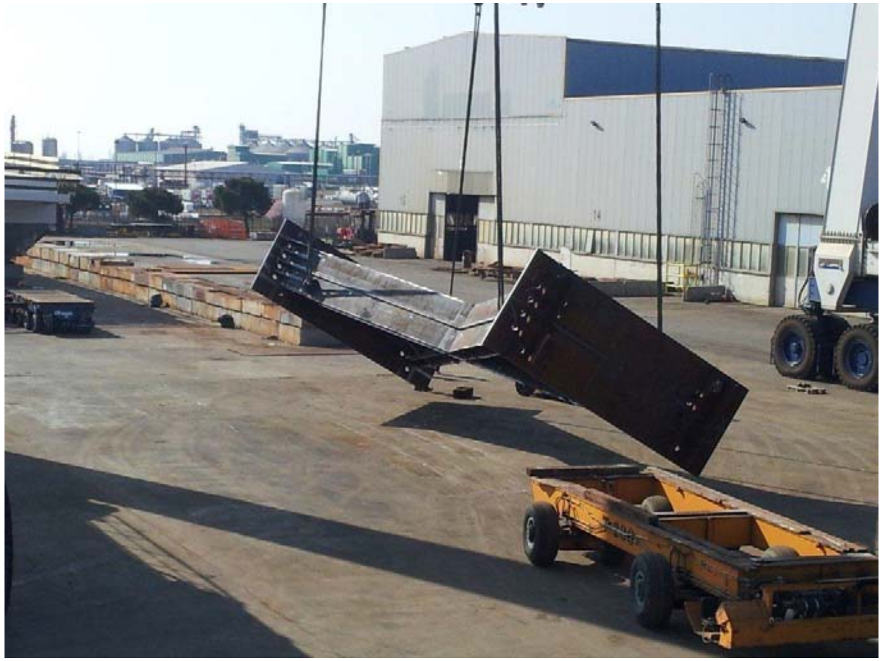


Temporary steel struts necessary to give stability to the pylons during construction, till the upper crossbeam installation.

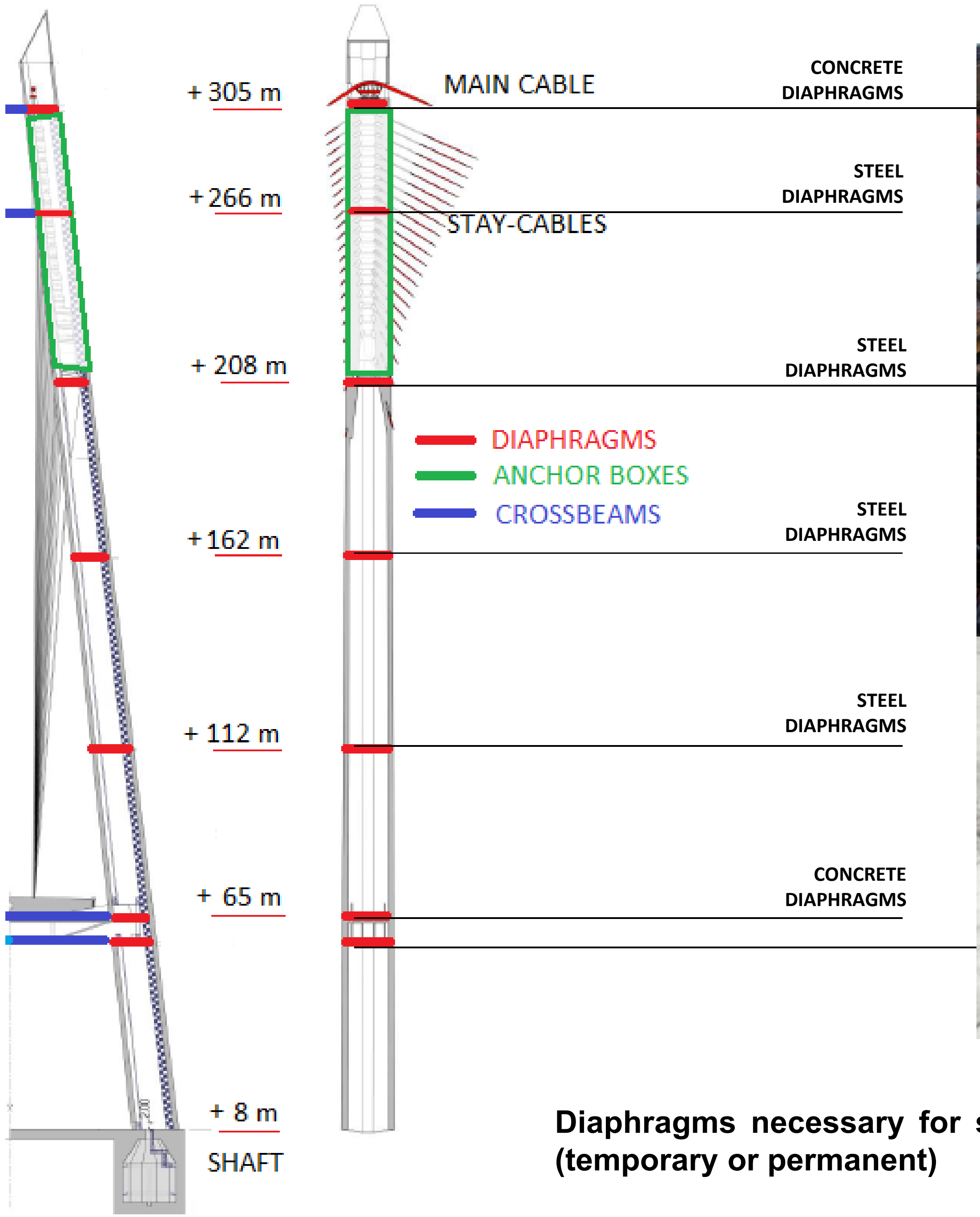
TOWERS

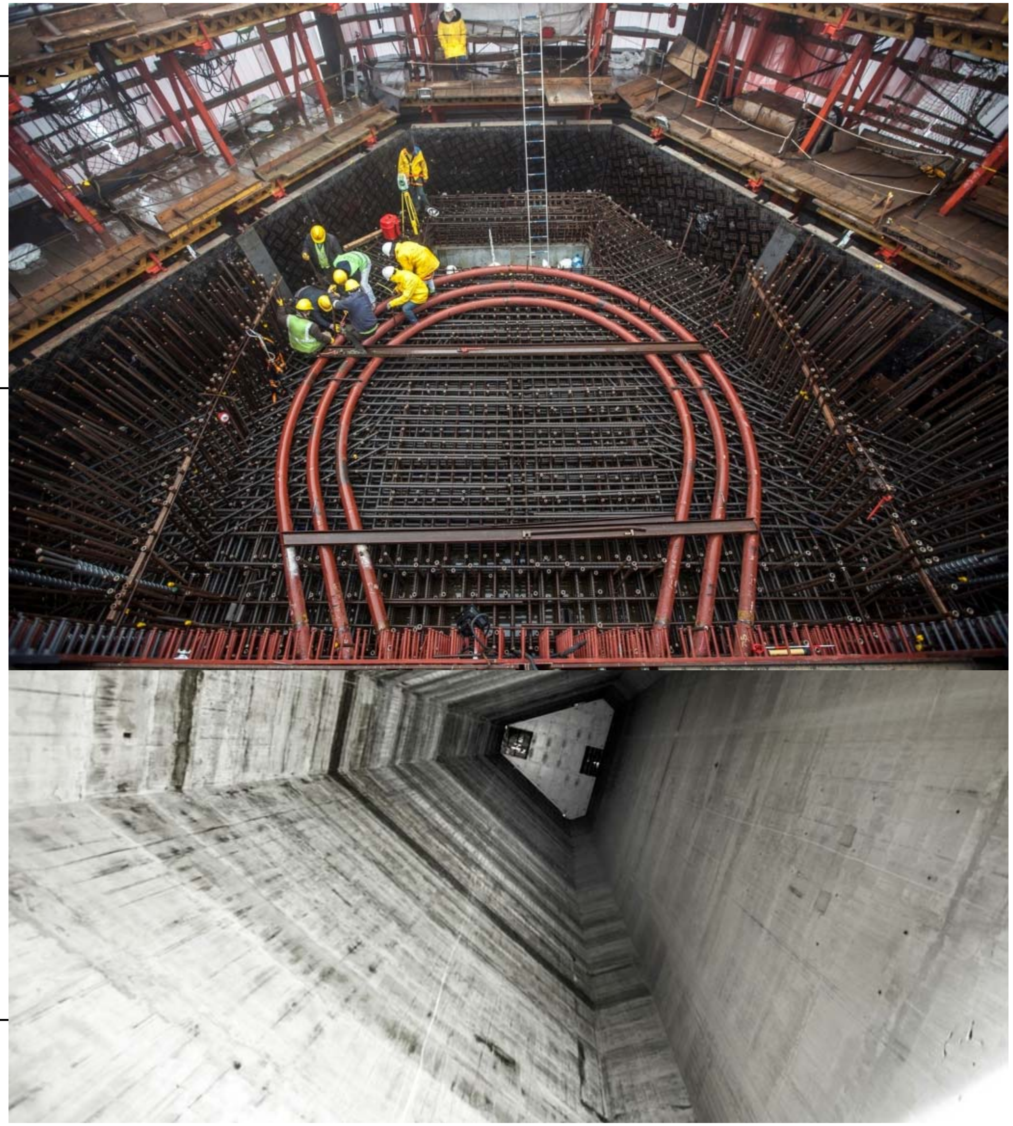
X - BRACINGS

TOWERS X-BRACINGS FABRICATION WORKS WERE COMPLETED BY ITALIAN COMPANY CIMOLAI



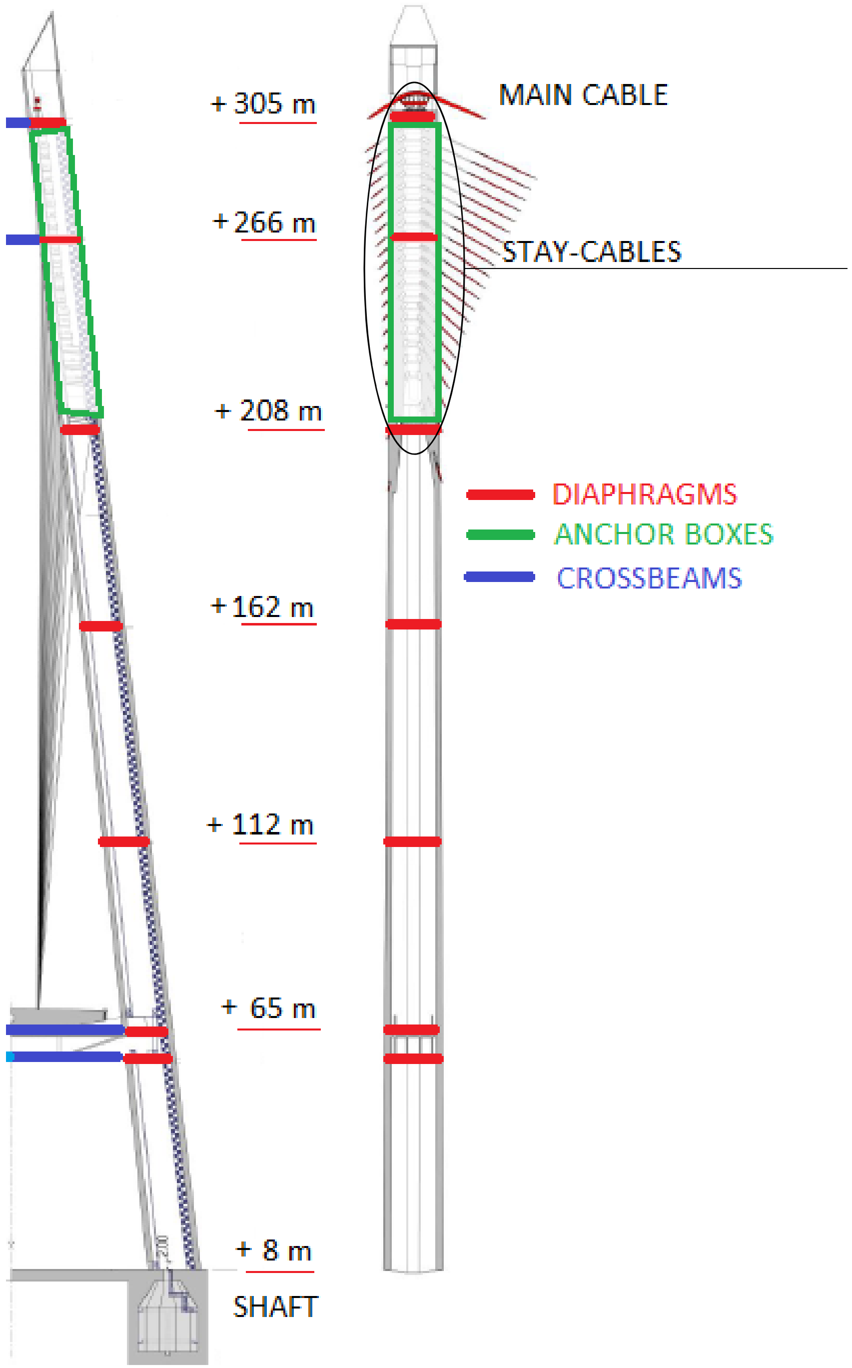
TOWERS DIAPHRAGMS

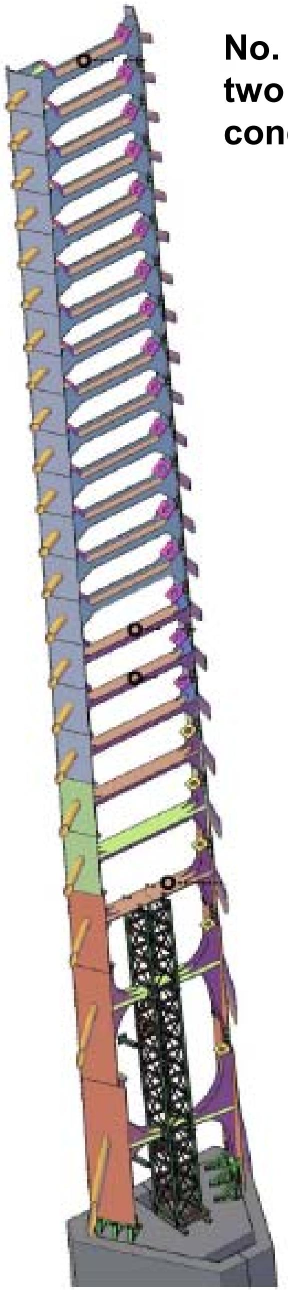




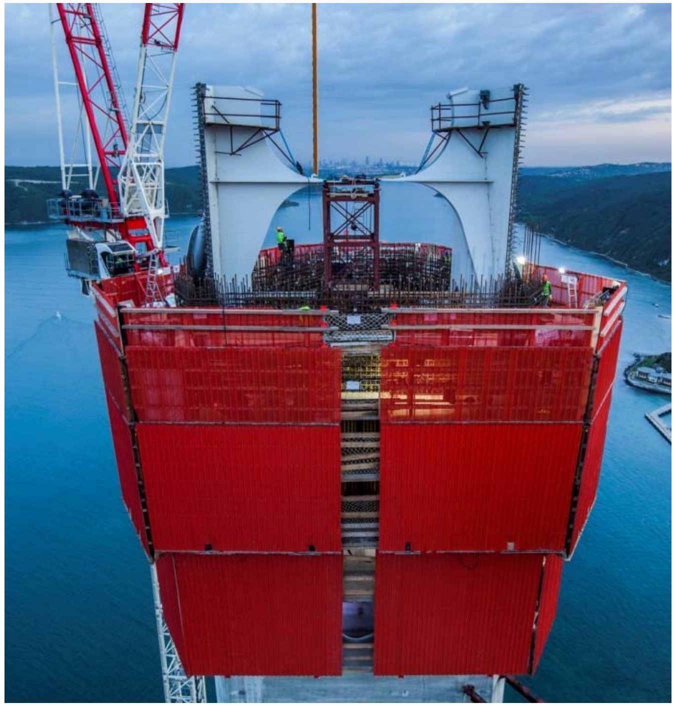
Diaphragms necessary for stiffen the zone of connection between the two legs (temporary or permanent)

TOWERS ANCHOR BOXES





No. 22 steel anchor boxes for the stiffening cables of the two span (Main e Side span) drowned in the tower concrete.

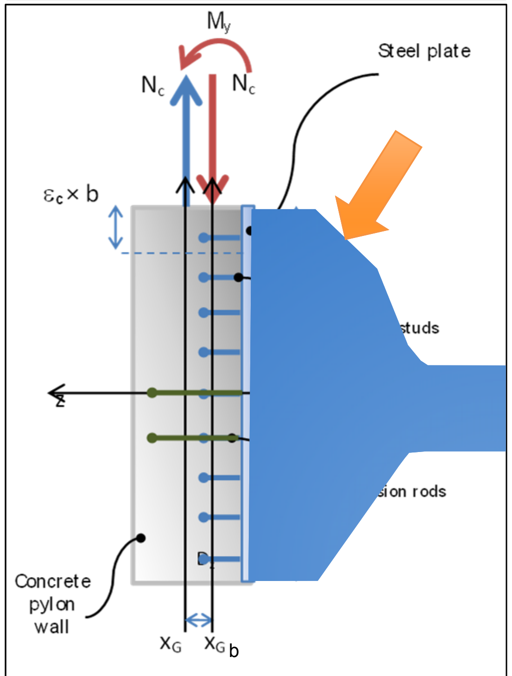


TOWERS ANCHOR BOXES

Connection to concrete pylon

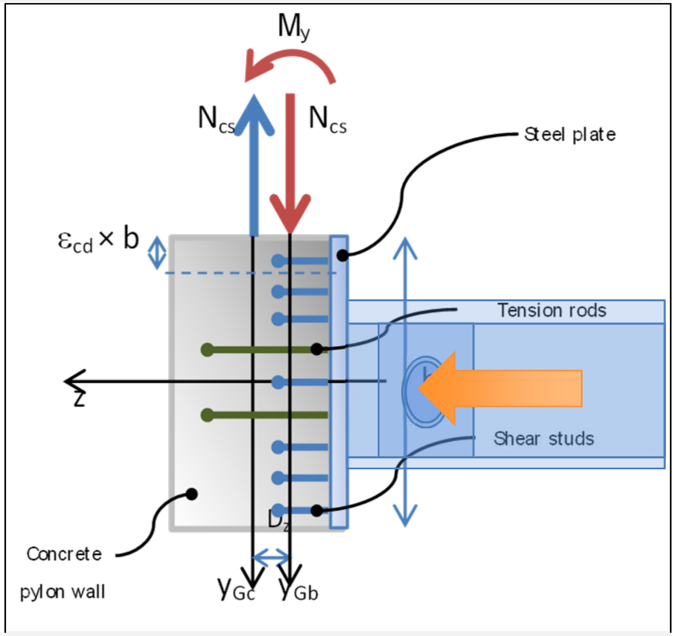
- Tension rods
- Shear Studs

Effect of Vertical Deformation



Side view

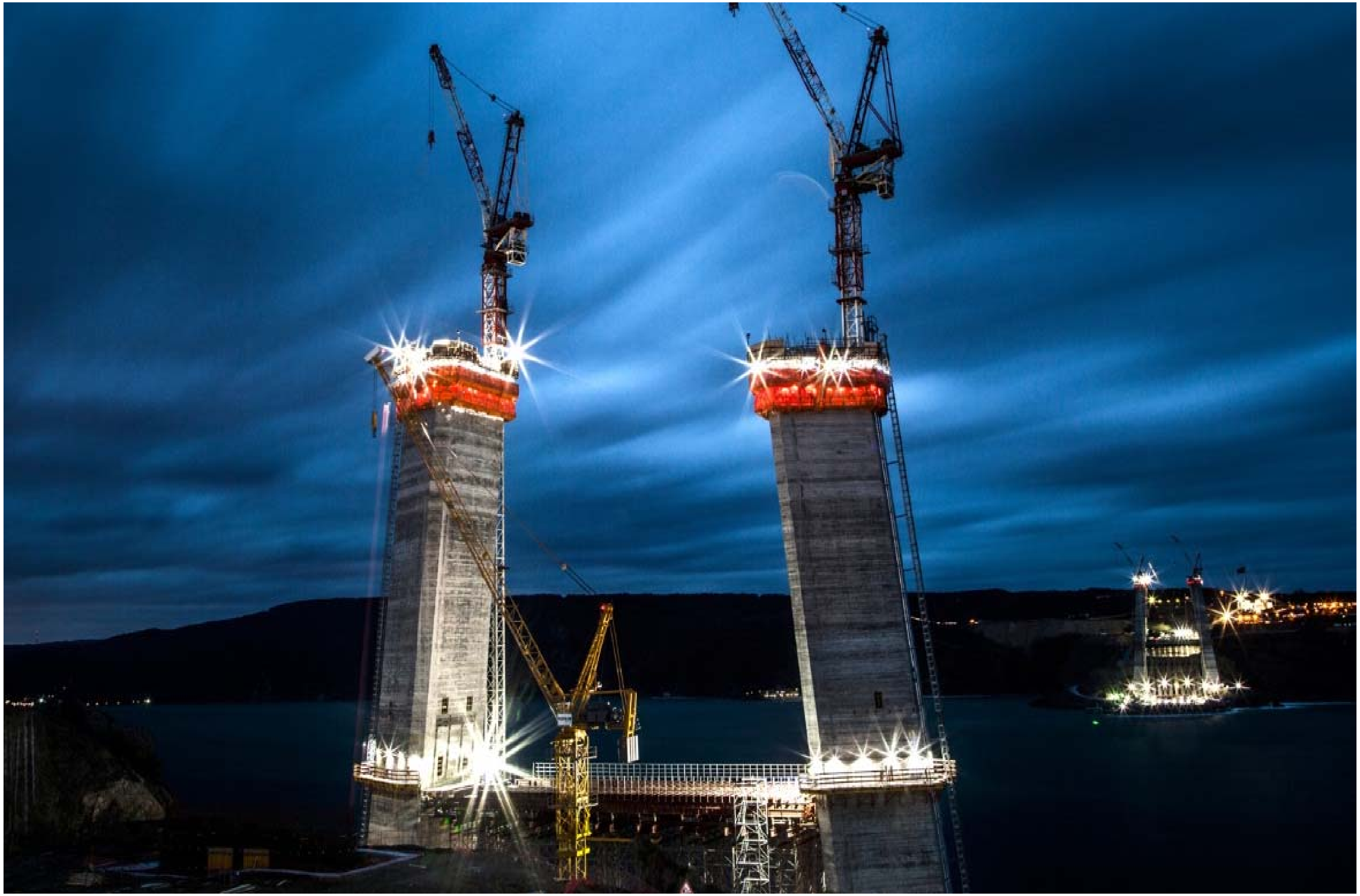
Effect of Shrinkage



Transverse section

ASTALDI

TOWERS



ASTALDI

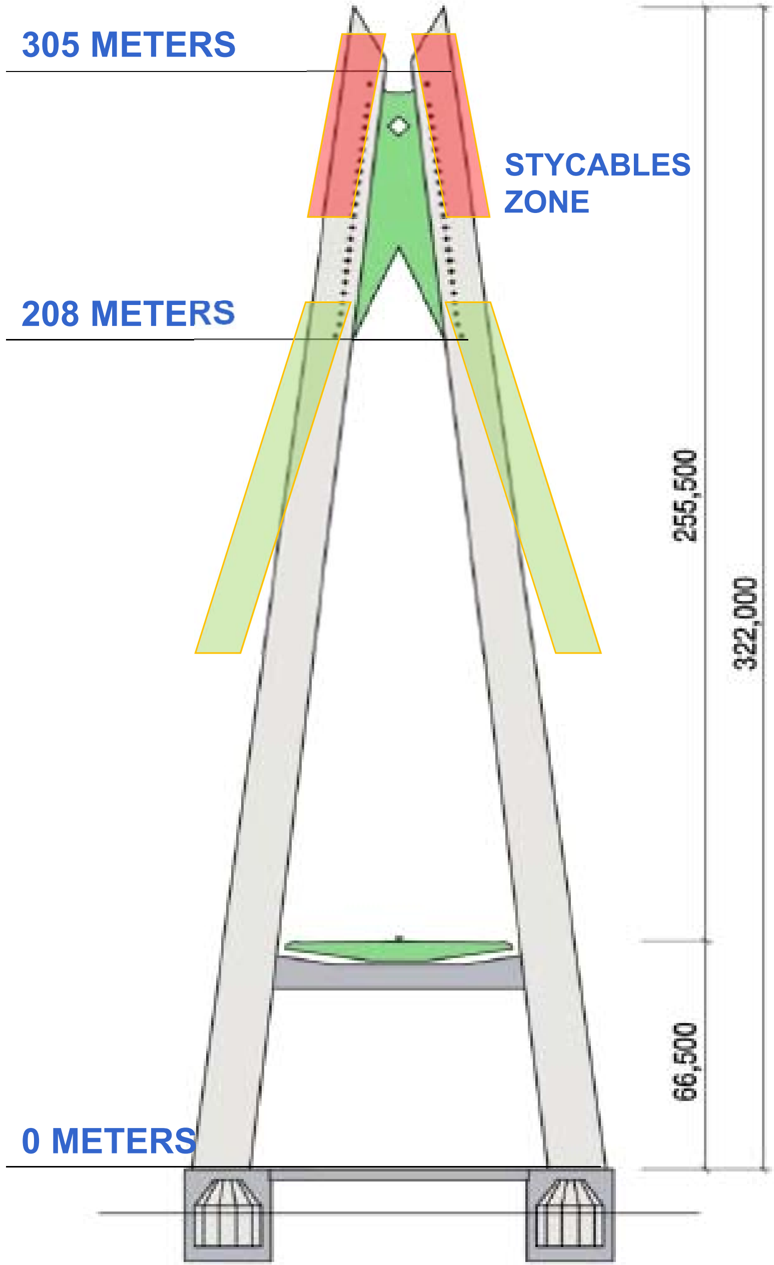
❖ Tower construction

TOWER ERECTION METHOD

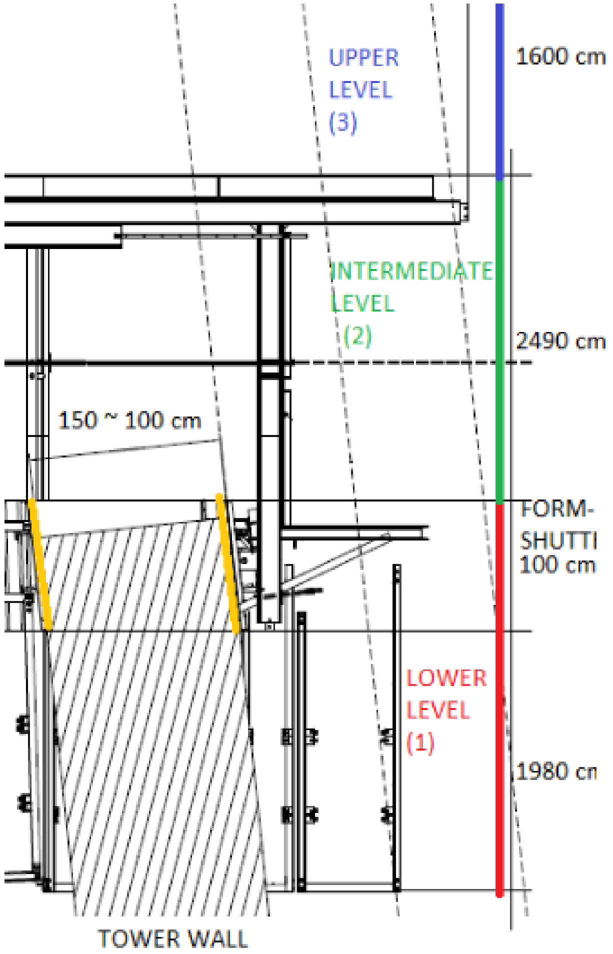
TWO TYPES OF SCAFOLDING WHERE USED:

CLIMBINGFORM, FROM 208 TO 305 m

SLIPFOM, FROM 0 TO 208 m

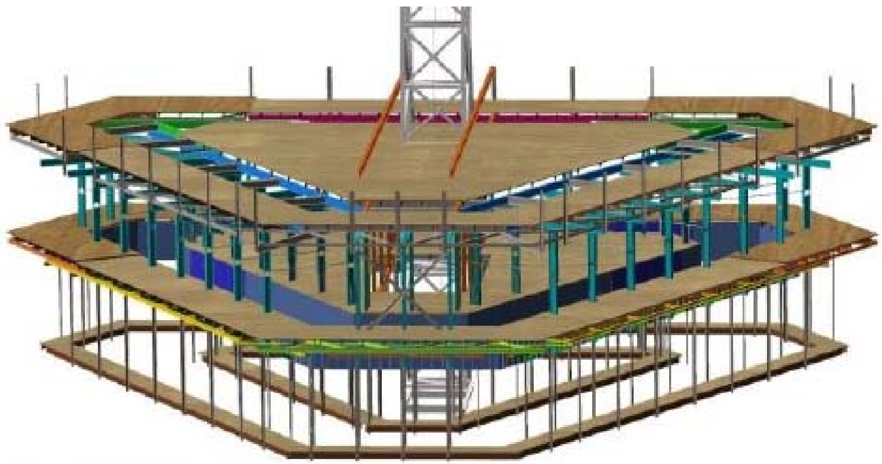


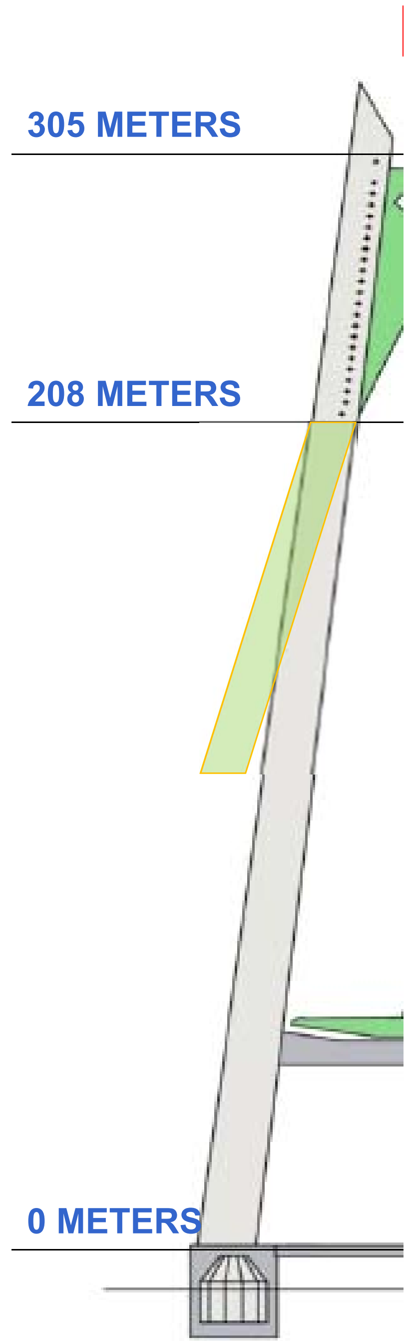
TOWER ERECTION METHOD

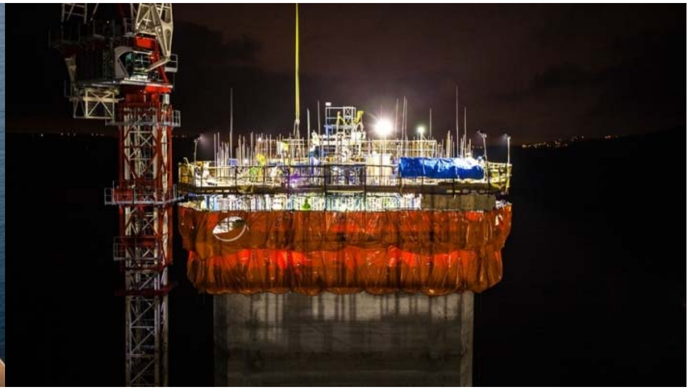


SLIPFORM

- WITH 3 WORKING LEVELS.
- THE CONCRETE IS POURED IN THE INTERMEDIATE LEVEL, EVERY 4 HOURS WITH LAYERS OF 20 CM
- CONSTANT AND SLOW ADVANCEMENT OF THE SCAFFOLDING (2 METERS PER DAY)



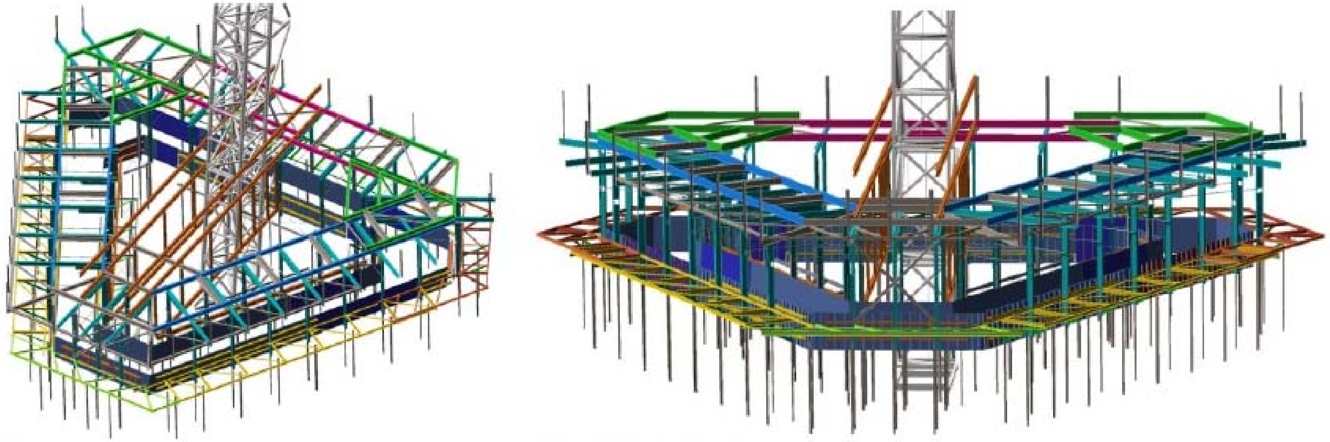




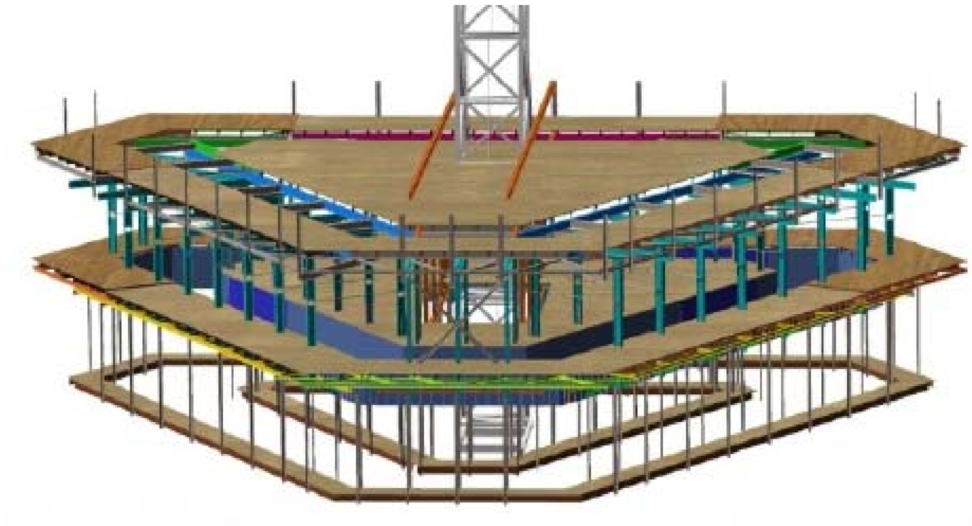
TOWERS

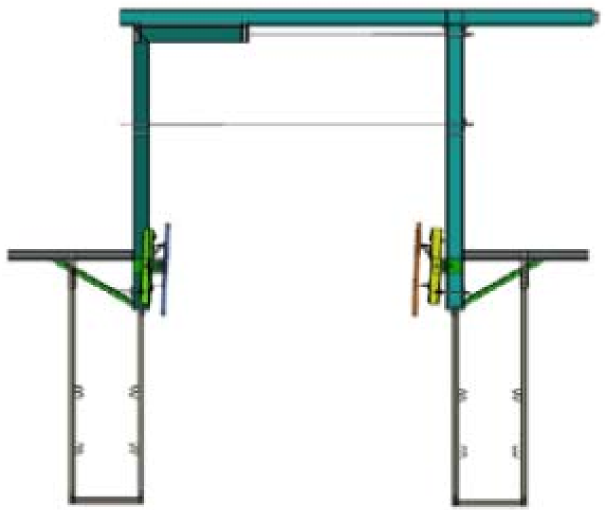
Jack and Pump view

SLIPFORM



Slipform assembly view





Slipform elevation is given by jackings on the concrete in the bottom of the shutter that has sufficiently stiffened to maintain its solid form

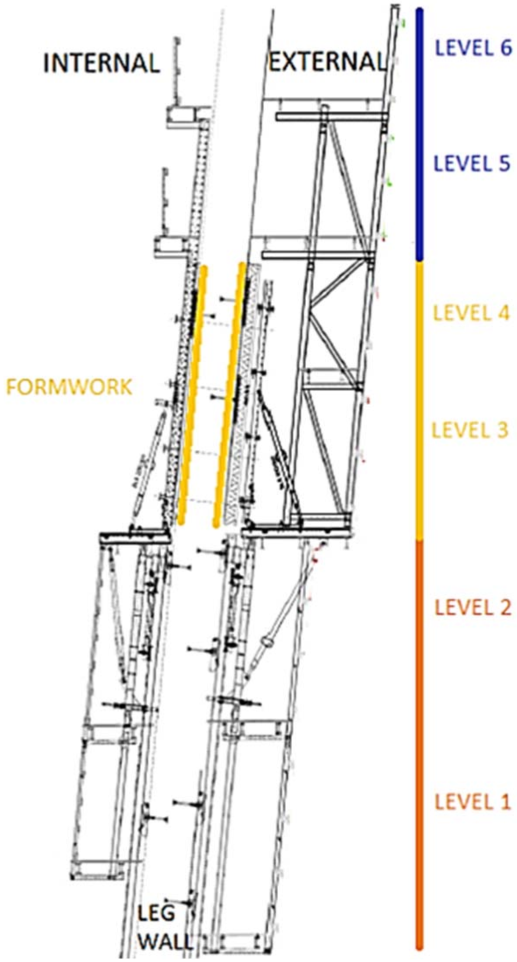
TOWERS

SLIPFORM

European Side – Installed Slipforms view

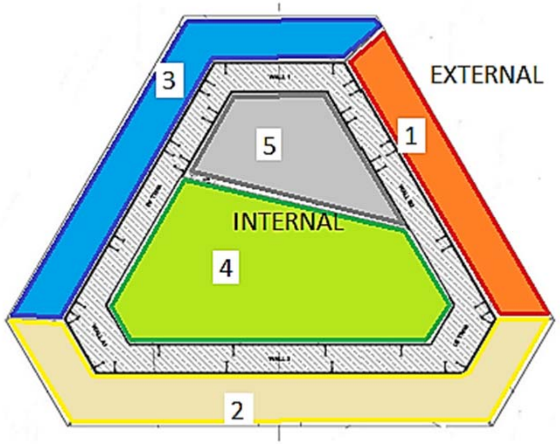
Concrete Works ongoing: nightshift

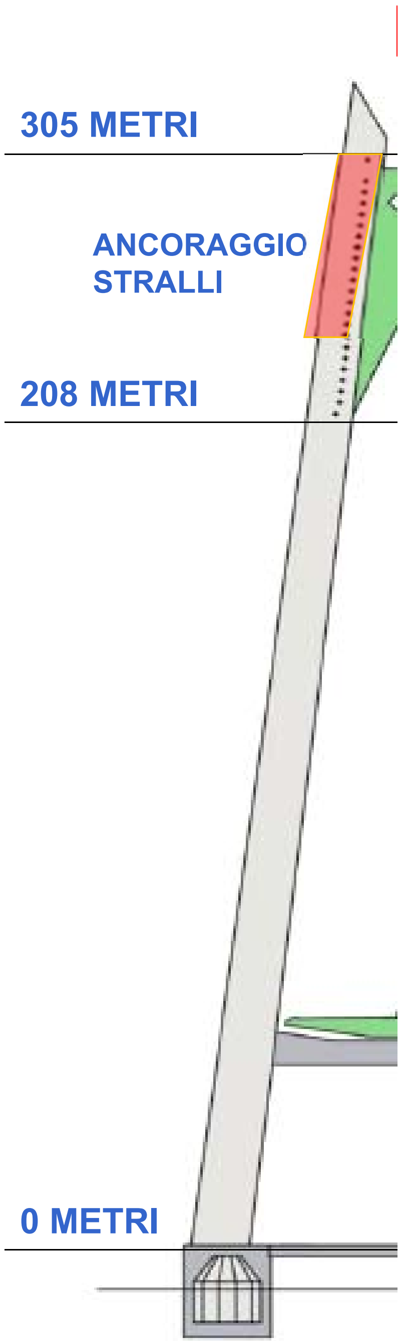
TOWER ERECTION METHOD



CLIMBINGFORM (ACS)

- WITH 6 LEVELS, AT LEVEL 3 THE SCAFOLDING IS LOCATED, HIGH 4,6 METERS.
- CONCRETE POURED EVERY 5 DAYS.
- IN ORDER TO ADVANCE IN ALTITUDE, THE FORMWORK STSTEM IS DEVIDED IN 5 MODULS, EACH ONE HAS TO BE LIFTED SEPARATLY FROM THE OTHERS.



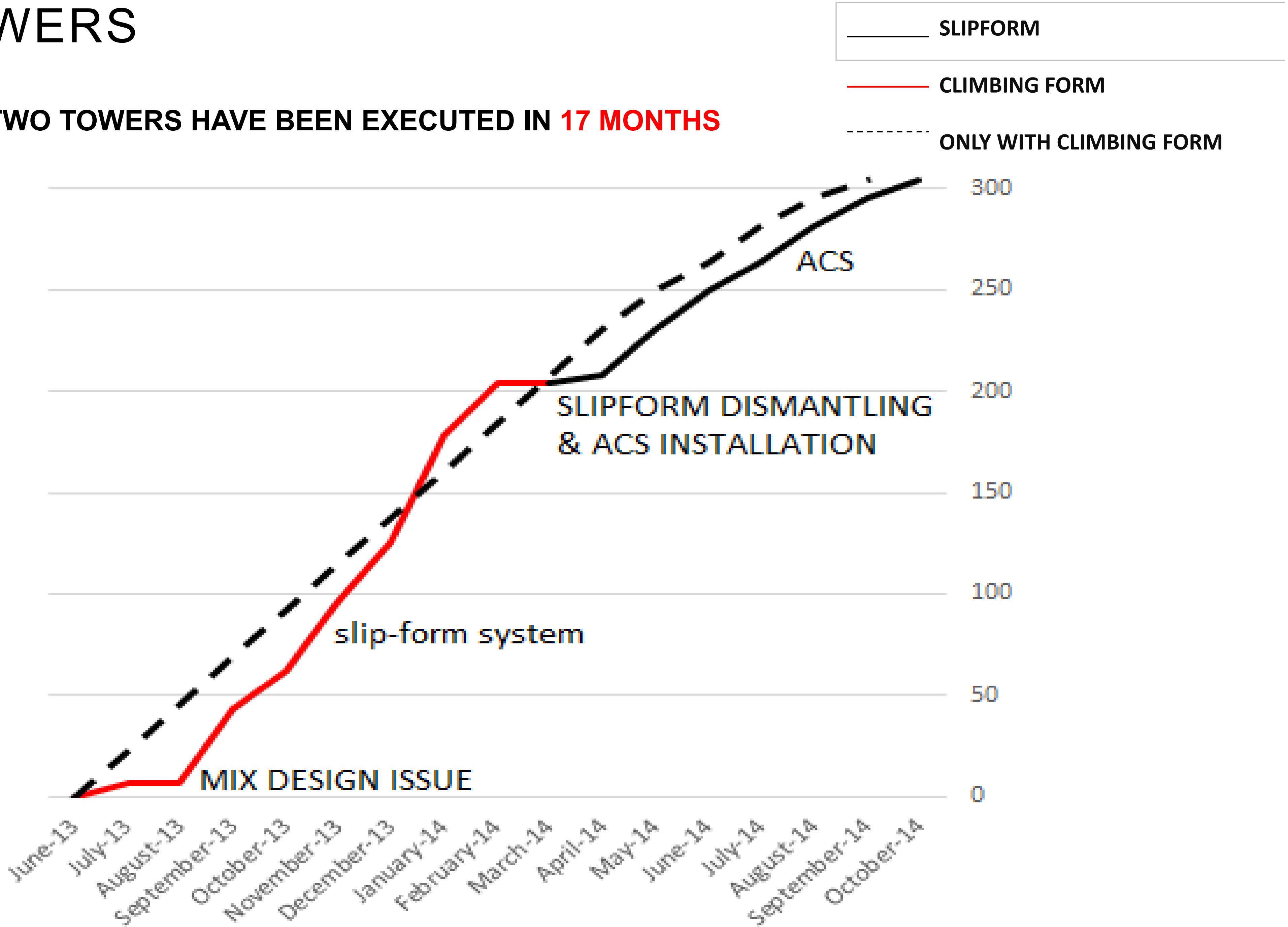


TOWERS

CLIMBINGFORM

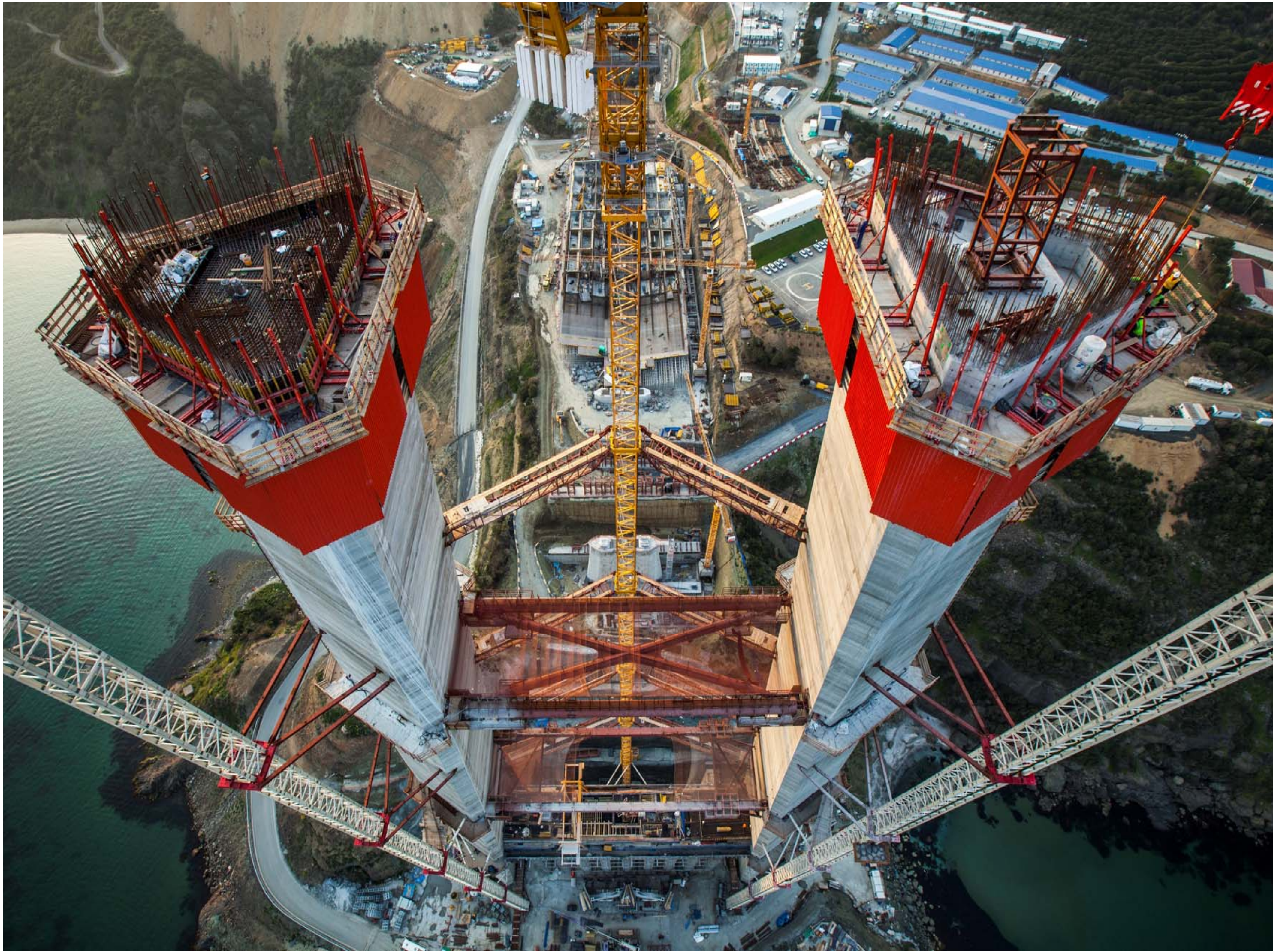
TOWERS

THE TWO TOWERS HAVE BEEN EXECUTED IN 17 MONTHS



TOWERS

SPECIAL POURING SYSTEM



TOWERS - TIP TOP

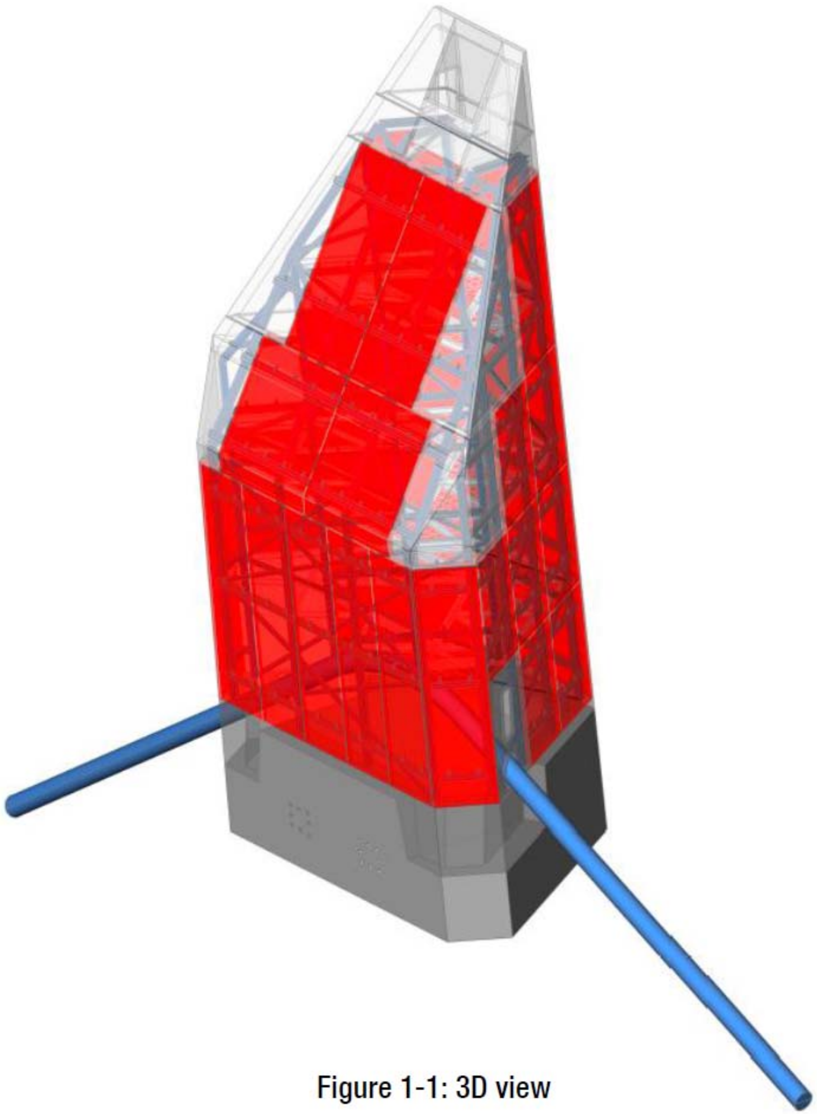
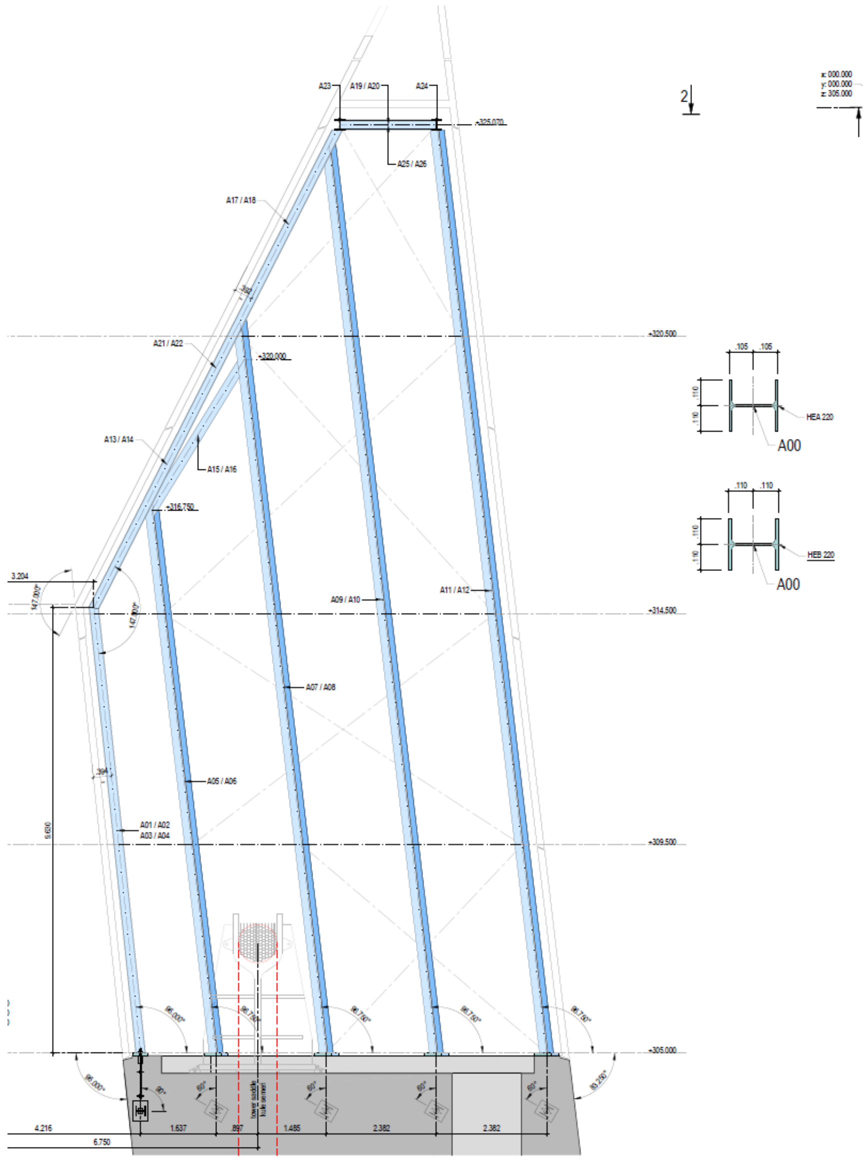


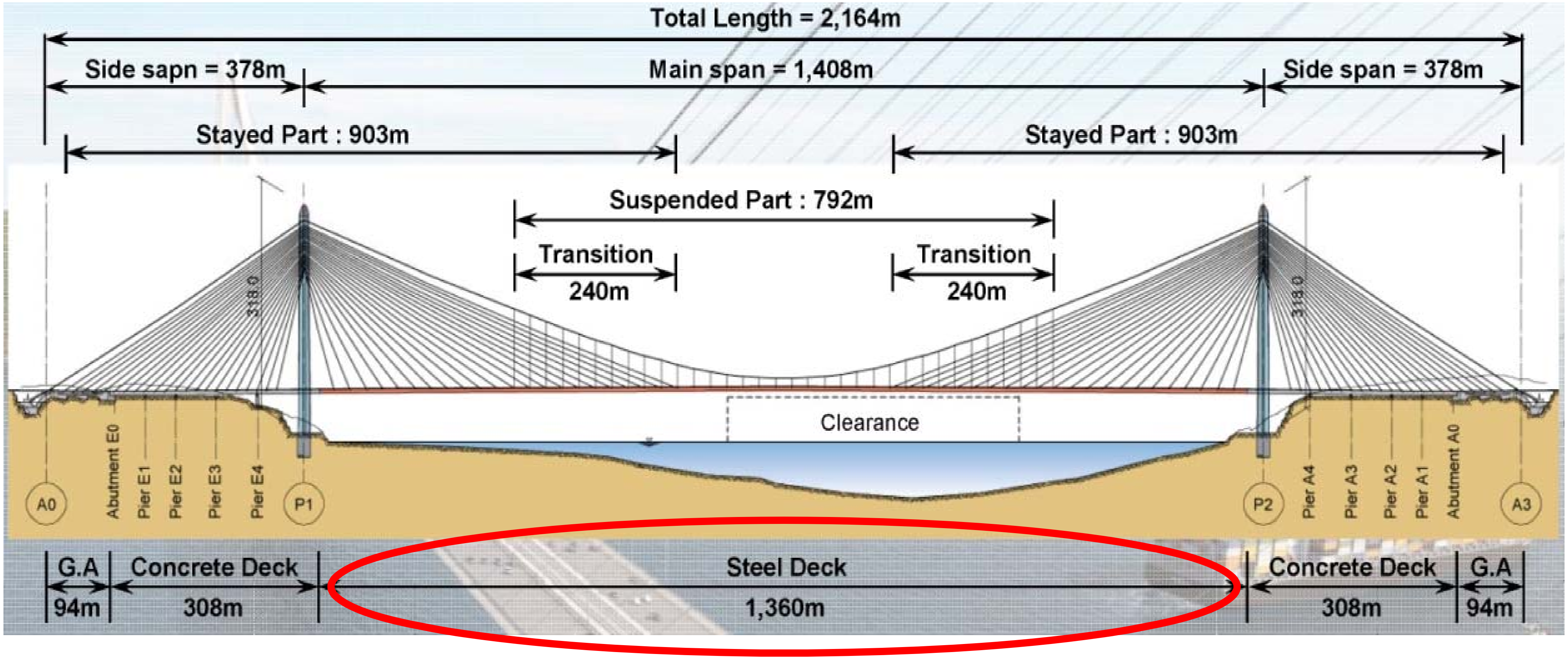
Figure 1-1: 3D view



❖ Steel deck

STEEL DECK

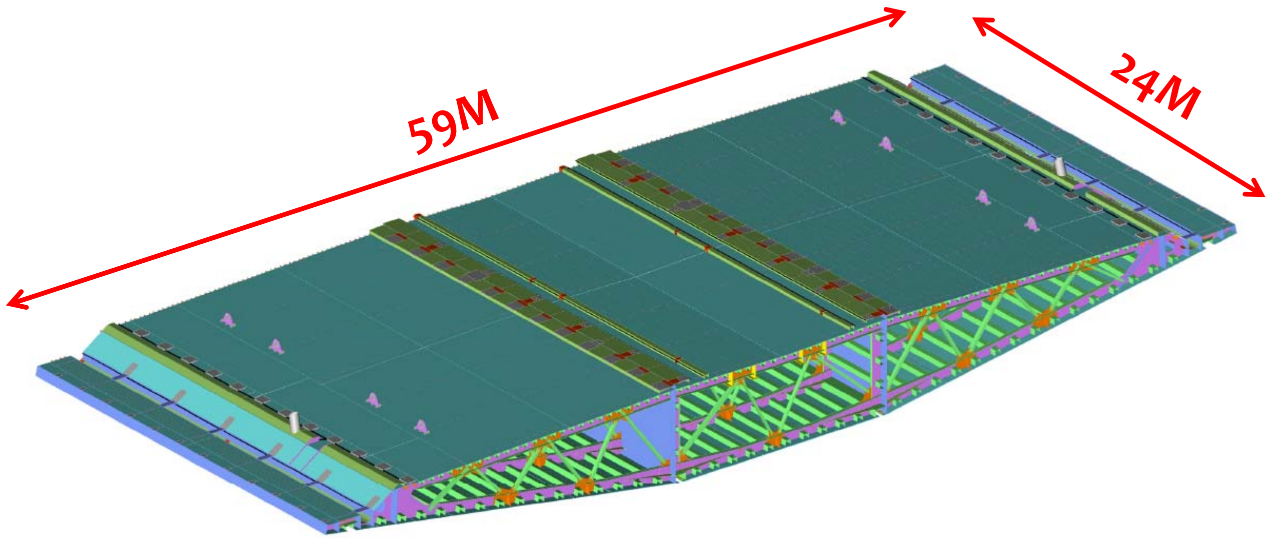
360M LONG – TOTAL WEIGHT: 46,950TONS – LIKE 5 TOUR EIFFELS
LARGEST ORTHOTROPIC DECK IN THE WORLD: 59M.



ASTALDI

STEEL DECK

STEEL DECK IS COMPOSED BY 59 SEGMENTS EACH WEIGHTING 850TONS.



Steel S460

Plates: 14 mm / 12 mm

Ribs : 8 mm / 7 mm

- STANDARD: EN 1090-2 Execution class **EXC4.** **Q**uality level B as per EN ISO 5817 with additional requirements for quality level B+ and for bridge decks (imperfection, porosity and inclusion limited)
- STEEL USED: mainly **S460M/ML** and **S355J0**, produced in South Korea
- MANUFACTURER: Turkish shipbuilder and steel factory Gemak Group

ASTALDI

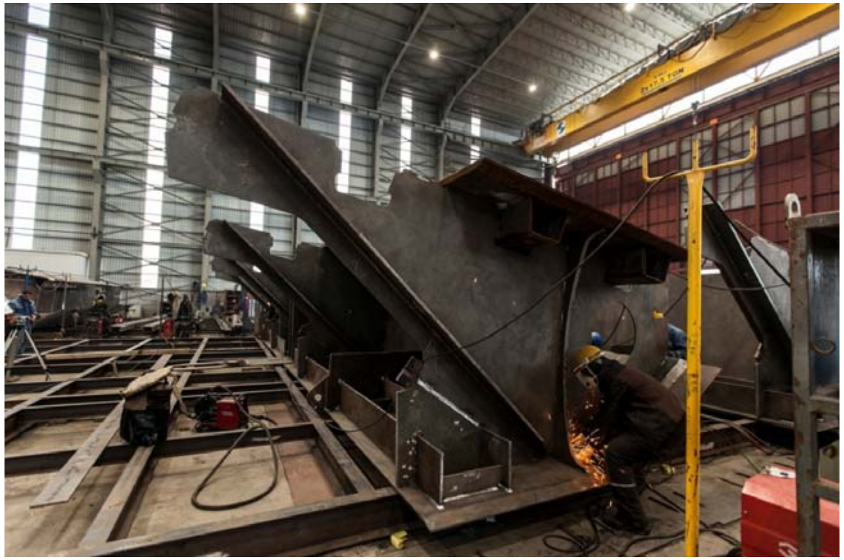
STEEL DECK

FABRICATION

ASTALDI

STEEL DECK

FABRICATION



STEEL DECK

FABRICATION

<u>U-RIB FIT-UP AND WELDING</u>

- A portal jack machine with interchangeable frames is used for the positioning of the U-Ribs on the deck plates
- Pre-deformation is applied before welding in order to reduce flame-straightening
- An automatic welding machine with 6 FCAW (Flux-cored arc welding) torches performs the longitudinal welds

STEEL DECK

FABRICATION

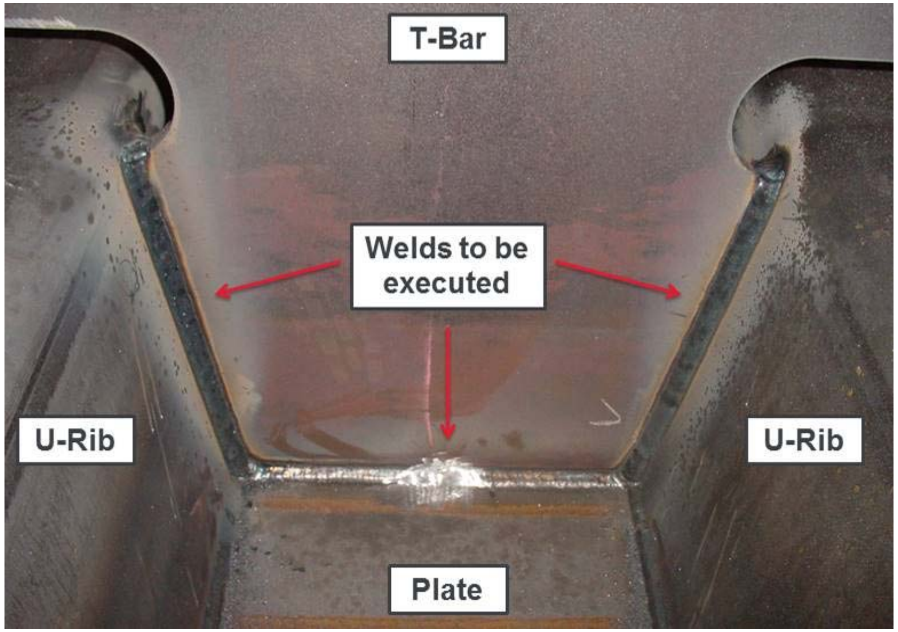
T-BAR FIT-UP AND WELDING

HIGH NUMBER OF COMPLEX AND CURVED WELDS TO BE PERFORMED.

AUTOMATED FCAW WELDING USING A ROBOT HAS BEEN SELECTED:

(1) QUALITY: REPEATABILITY OF THE MOVEMENT AND THE WELDING PARAMETERS

(2) PRODUCTIVITY: WORKING ALMOST CONTINUOUSLY



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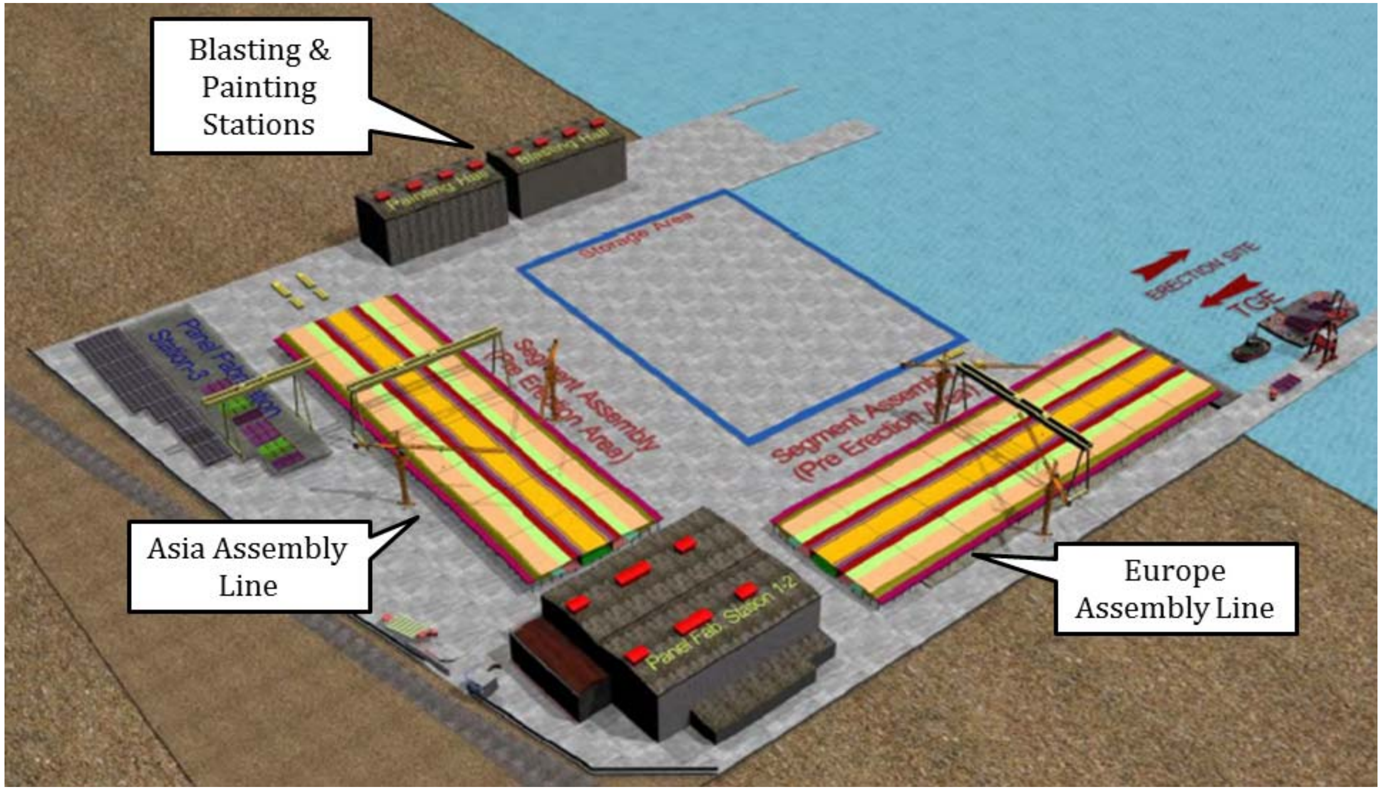
STEEL DECK

ASSEMBLY

<u>FINAL ASSEMBLY YARD</u>

- ❖ TWO ASSEMBLY LINES (8 SEGMENTS EACH), EUROPE AND ASIA SEGMENTS
- ❖ TWO PORTAL CRANES 70M WIDE WITH 2X35TON HOOKS
- ❖ BLASTING / PAINTING HALLS (28M WIDE, 63M LONG) BUILT AD HOC FOR THIS PROJECT

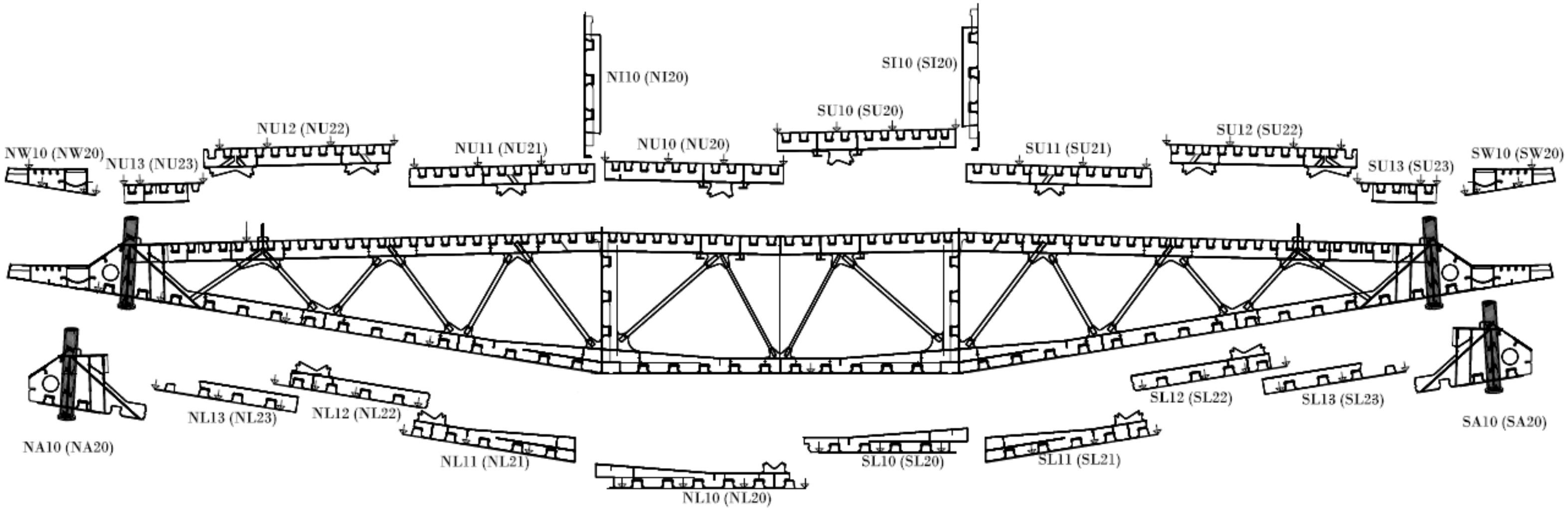


STEEL DECK

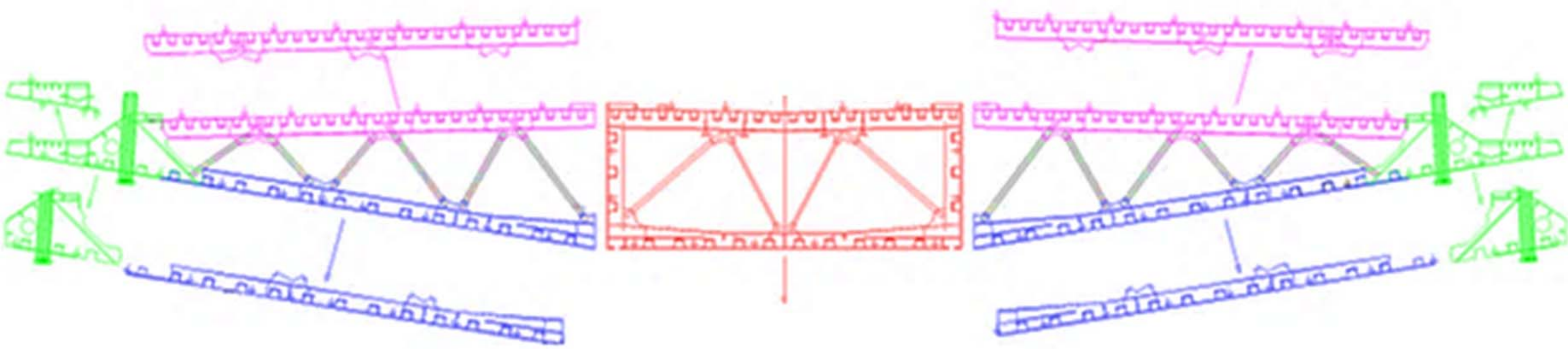
ASSEMBLY

- <u>PREASSEMBLY OF PANELS</u>

MAXIMIZATION OF INDOOR PREASSEMBLY ACTIVITIES



44 elementary panels per segment



18 “superpanels” per segment assembled on Yard

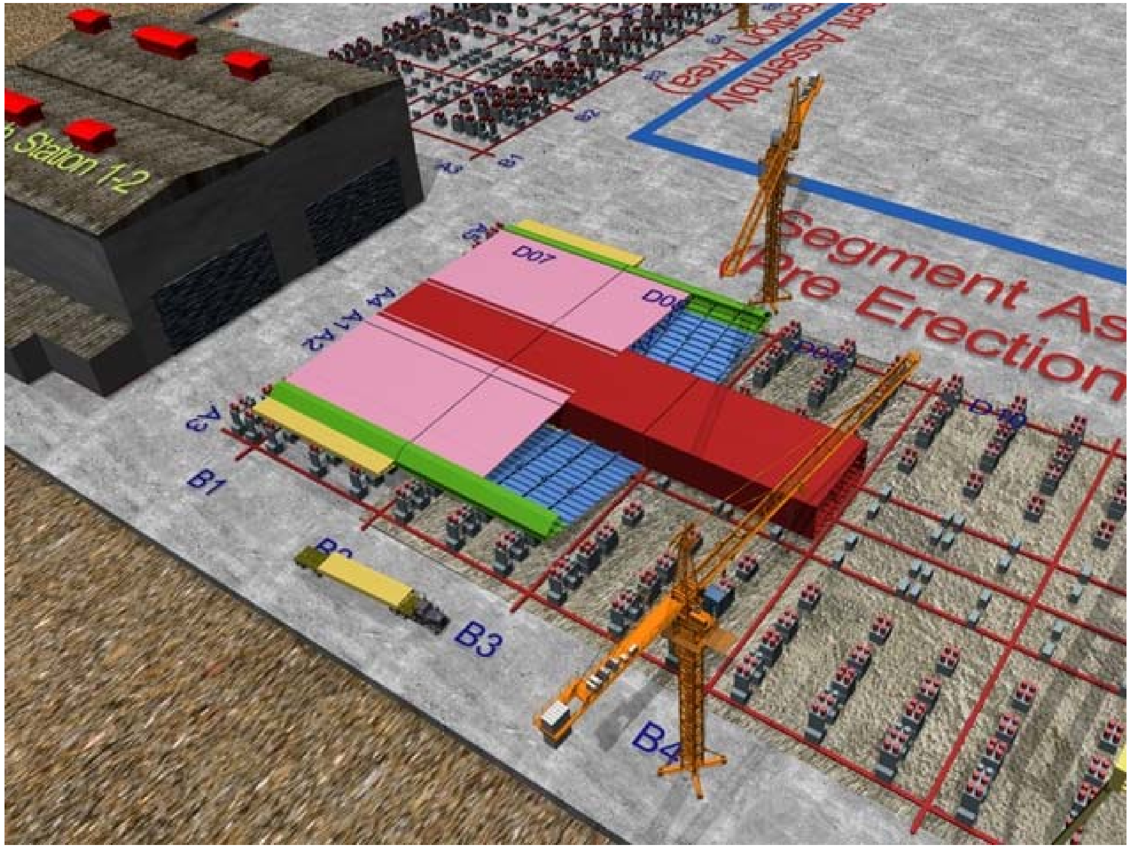
ASTALDI

STEEL DECK

ASSEMBLY

<u>Segment Assembly</u>

- Trial Assembly to be executed between 3 consecutive panels
- Blasting executed with WG40 (50%) + WG50 (50%) abrasives to achieve a ISO 8501-1 SA2½
- Painting system consists of 4 layers (primer, two epoxy and a polyurethane top-coat) for total 470mm DFT



ASTALDI

STEEL DECK

D00 WITH SPECIAL FLOTING CRANE

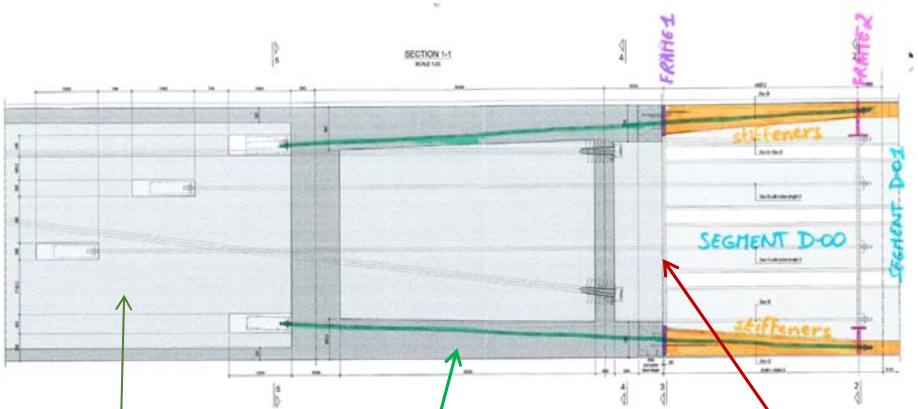
STEEL DECK

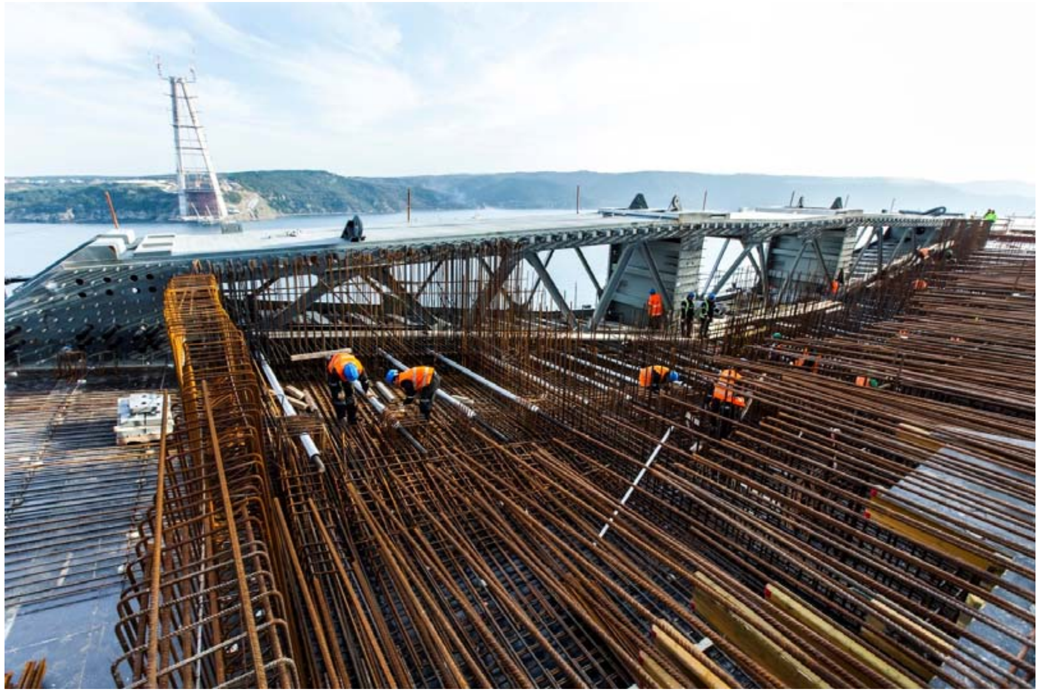
ERECTION D00

STEEL DECK

D00 CONNECTION WITH CONCRETE DECK

Segment D00 – connection between
concrete deck and steel deck





Prestressing to ensure the connection

« Classical » concrete prestressing

Connection S6 - D00
N. 176 studs

STEEL DECK

ERECTION D01


hareket

STEEL DECK

ERECTION D01

STEEL DECK

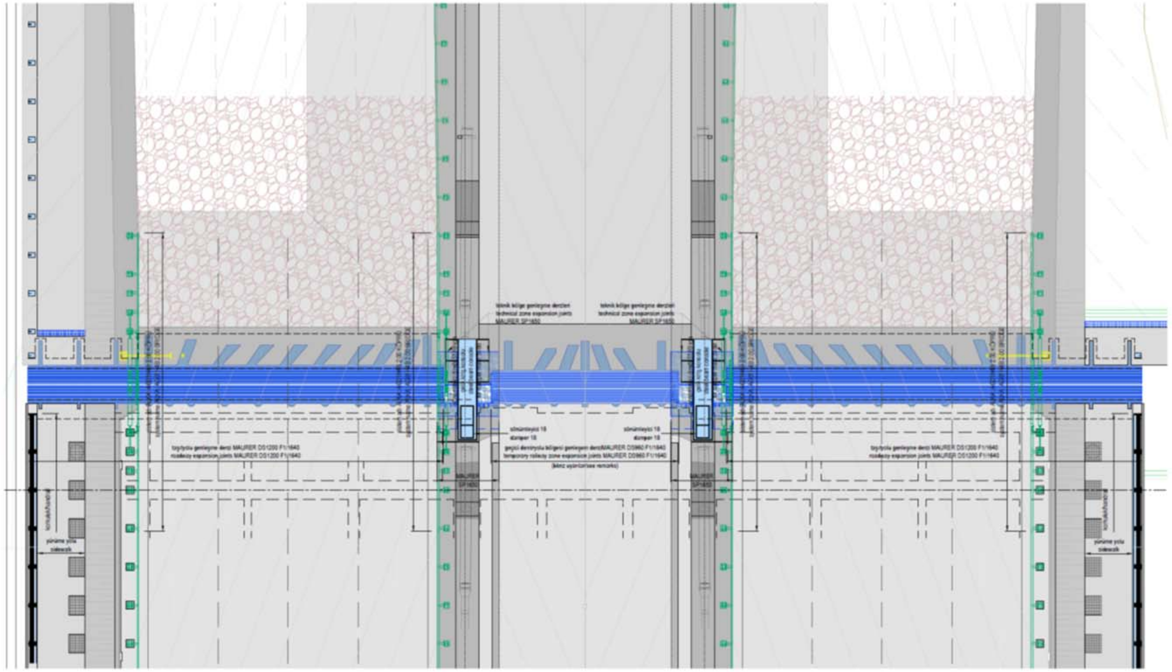
ERECTION D01

ASTALDI

STEEL DECK

EXPANTION JOINTS

-1200 - +1460



STEEL DECK

PAVEMENT & WIND BARRIERS

IMPALCATO METALLICO	
Stone Mastic Asphalt	**4 cm**
Mastic Asphalt	**3 cm**
Take coat (mano di attacco)	Metalcrilato polimero HR
Impermeabilizzazione MMA	Metli Metalcrilato (resina)
Primer (spray)	Anti corrosivo per metalli

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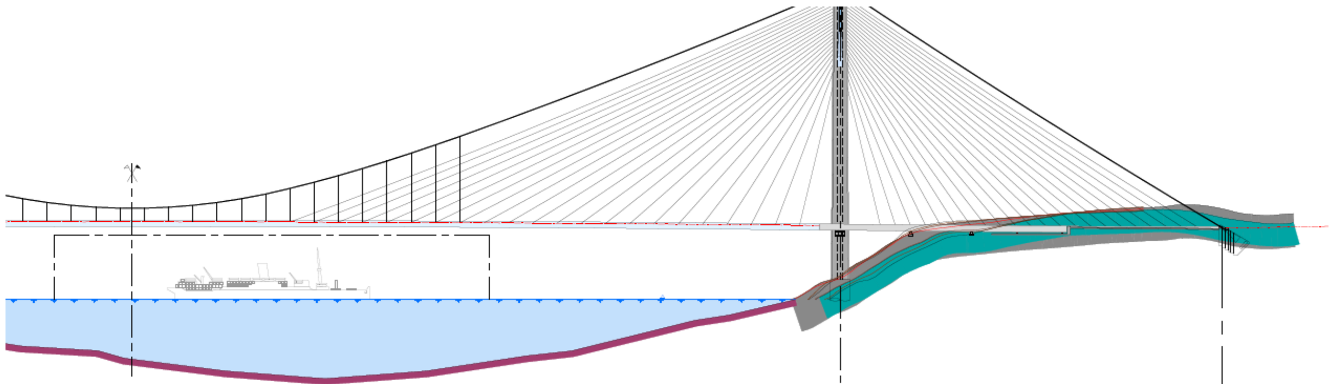
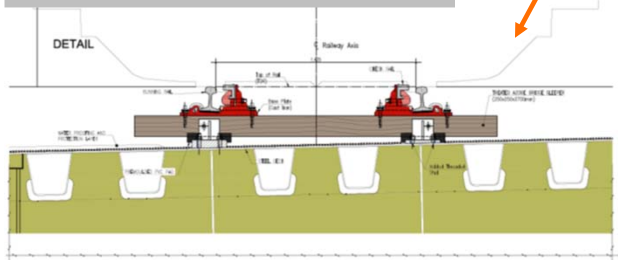
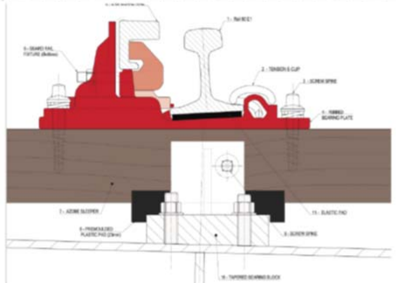
TRACK SYSTEM



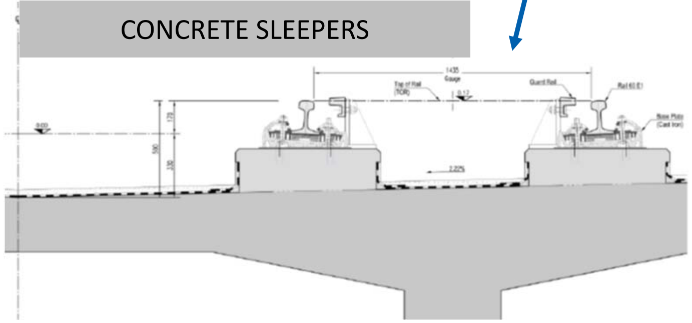
WOODEN SLEEPERS





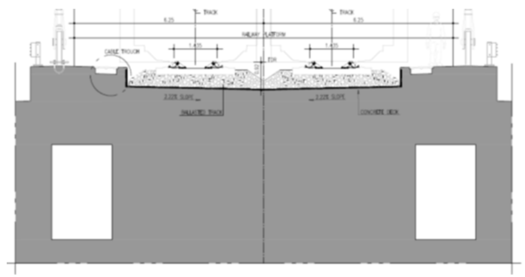
TOT WEIGHT (1 track)	7 kN/m

CONCRETE SLEEPERS



TOT. WEIGHT (1 track)	12,9 kN/m

BALLAST



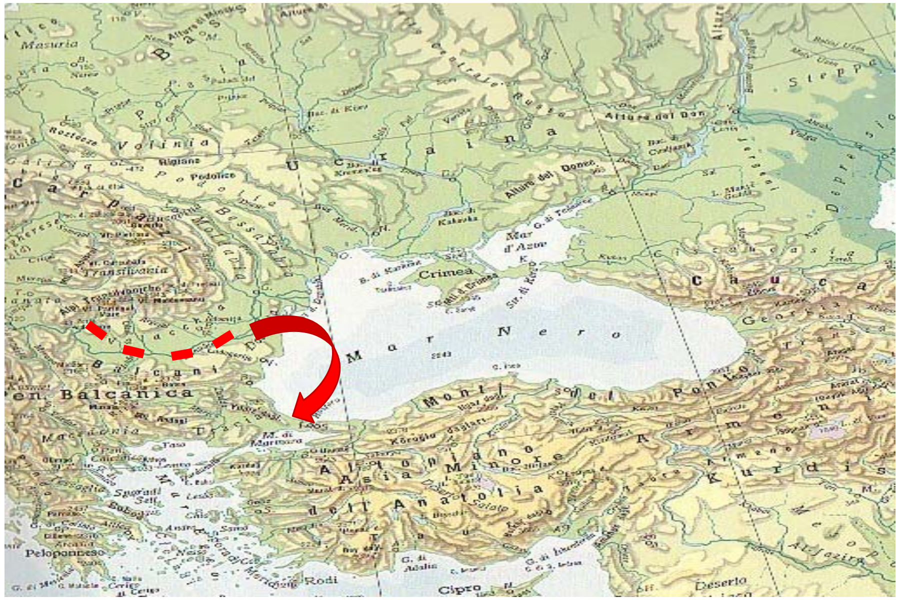
BOSPHORUS - 1954

Ice in the Bosphorus the 23rd February 1954

BOSPHORUS - 1954

Due to the ice present in the Bosphorus people walked over the ice, in a sea water, the connection with vessel were interuptd in the Bosphorus but also in Halic sea.

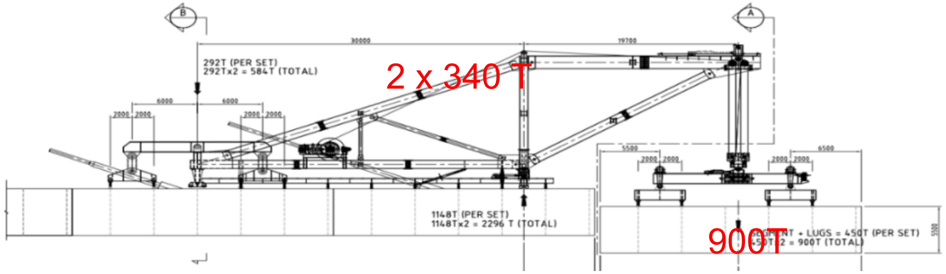
This situation continued till 6 of March 1954.

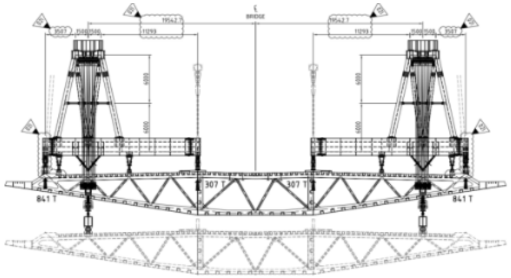


❖ Erection system

ERECTION SYSTEM

1. <u>CANTILEVER PART</u>
   Erection of the cantilever segments with two derrick cranes.
   From segment D00 to segment D020.

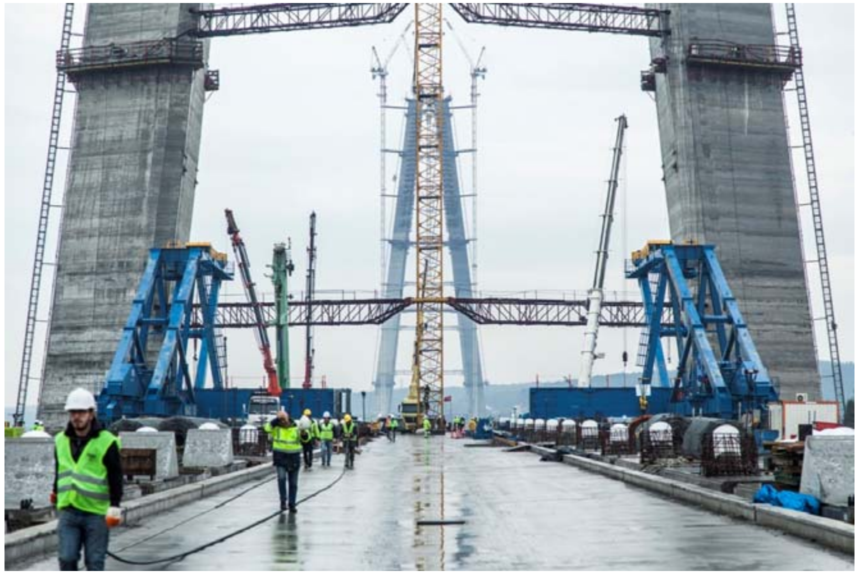




2. <u>SUSPENDED PART</u>
   Erection fo the suspended part with two Lifting Gantry.
   From segment D21 to key segment D99.

DERRICK CRANES

ASSEMBLY

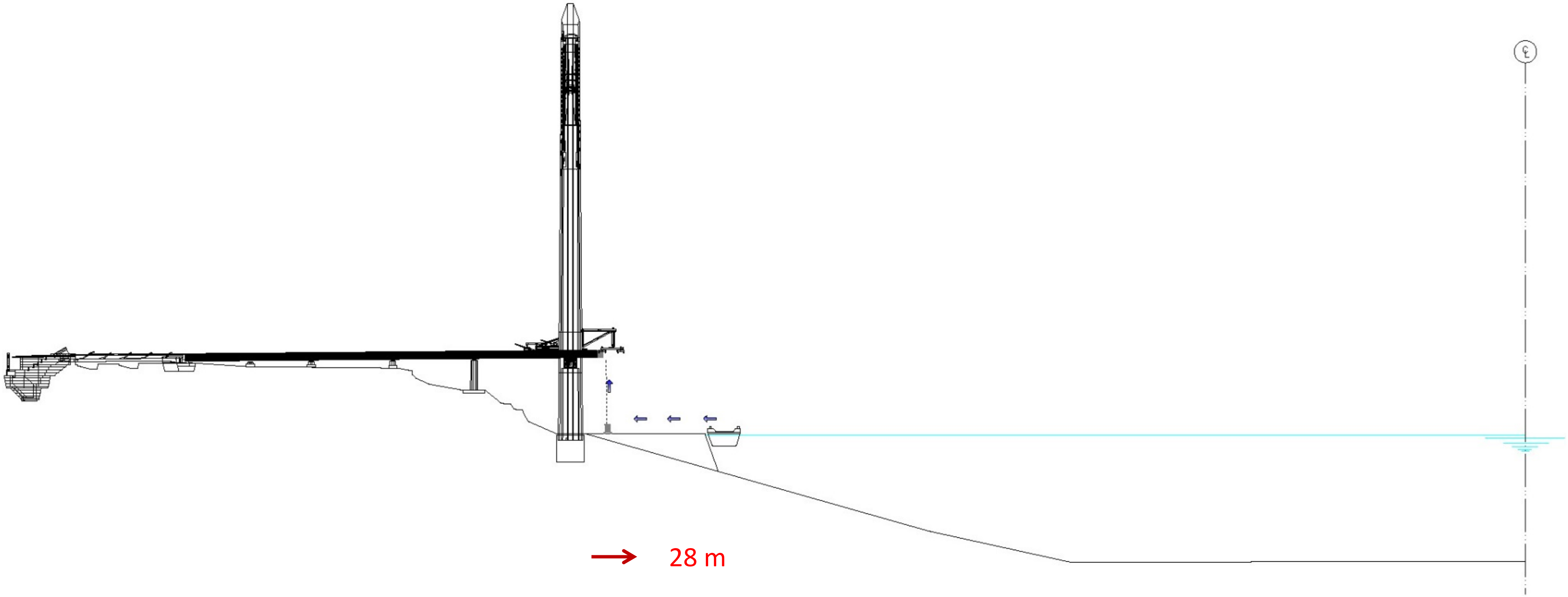


ASTALDI

DERRICK CRANES FUNCTIONALITY - NRS

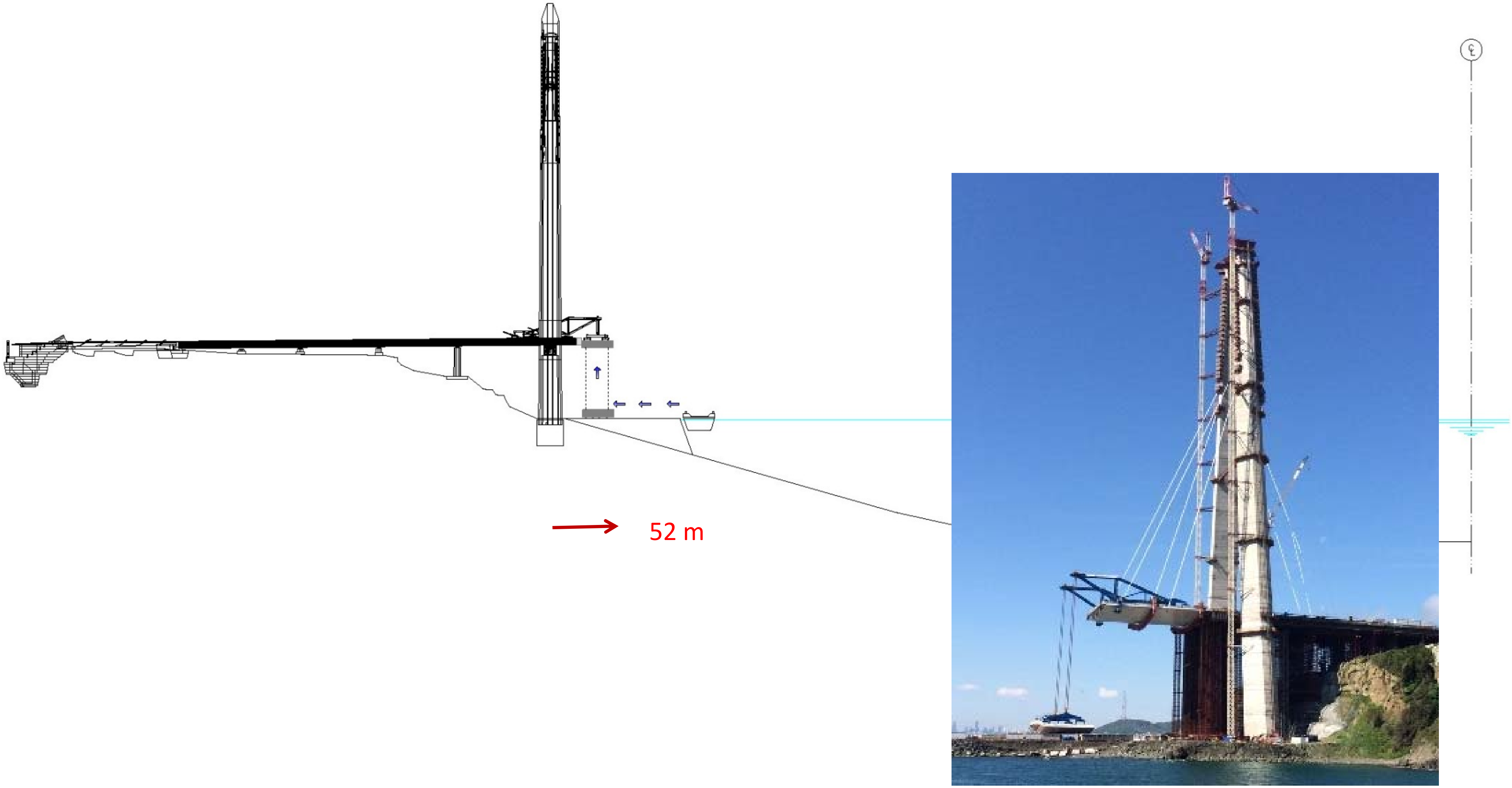
CANTILEVER
Segment D00 – 4 m

- Installation, launch and anchorage of the derrick cranes
- Discharge of the connection segment D00 from the barge, translation to the vertical position, erection of the steel segment D00 (4 m) from the ground
- Connection of D00 to concrete deck, pouring and post-tensioning
- Release of the derrick cranes



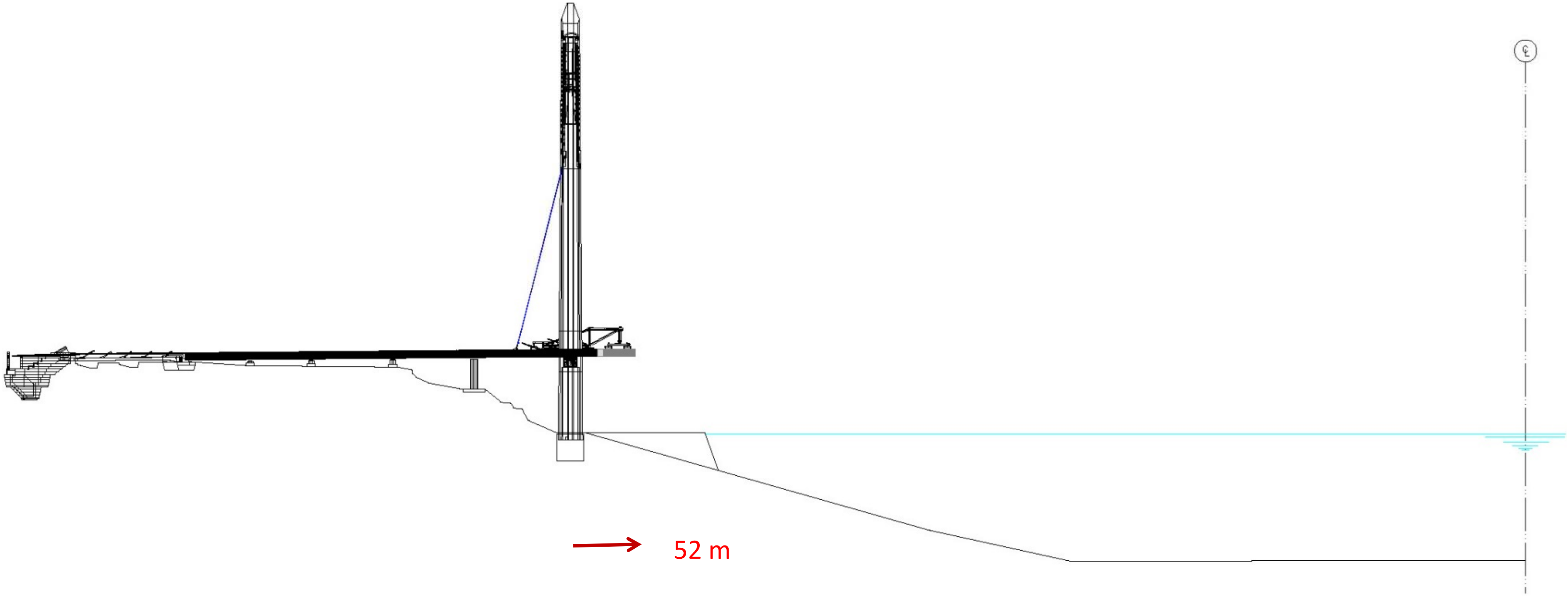
CANTILEVER
Segment D01 – 24 m

- Derrick cranes launching of 24 m
  Discharge of the segment D01 from the barge, translation to the vertical position, erection of the steel segment D01 (24 m) from the ground
- Minimum welding connection between D00 and D01



CANTILEVER
Segment D01 – 24 m

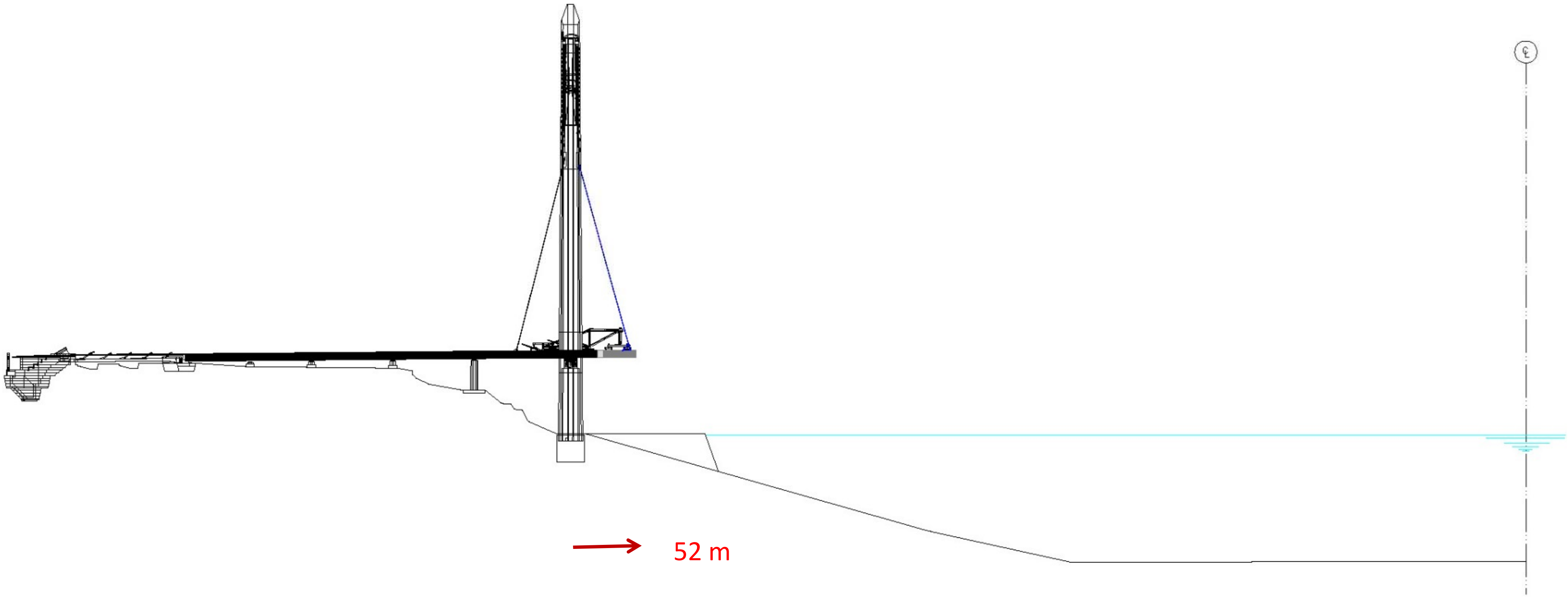
- Installation of stay cables S01B in the back span
- Release of segment D01 with only its weight



ASTALDI

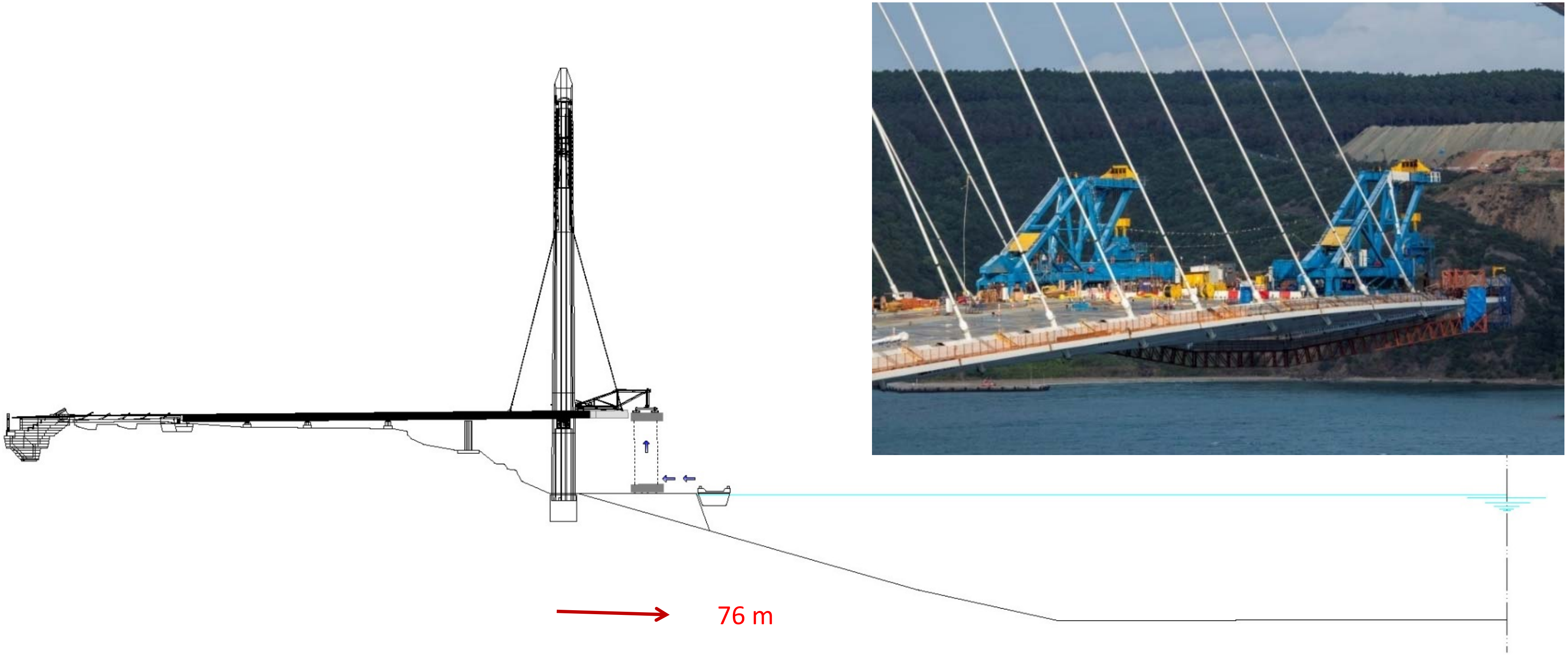
CANTILEVER
Segment D01 – 24 m

- Installation of stay cables S01M in the main span



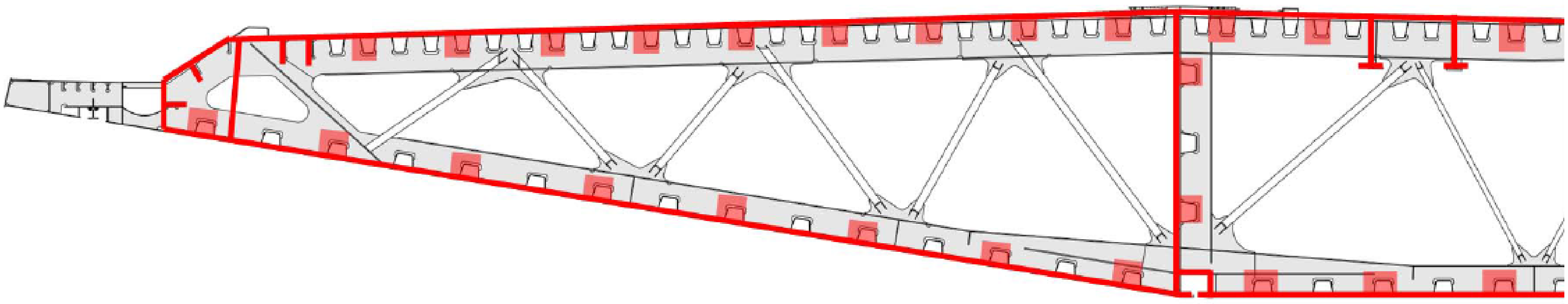
CANTILEVER
Segment D02 – 24 m

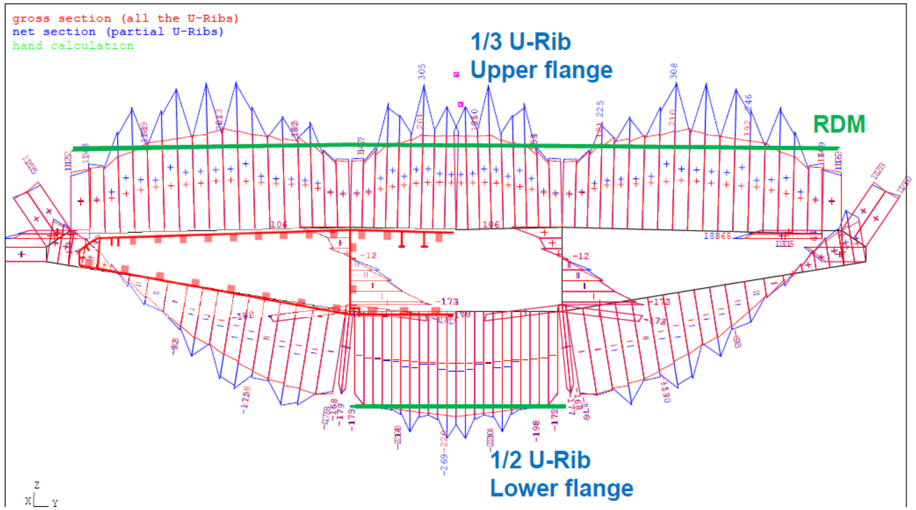
- Derrick cranes launching
- Erection of segment D02 (24 m), always from the ground
- Welding connection between D01 and D02

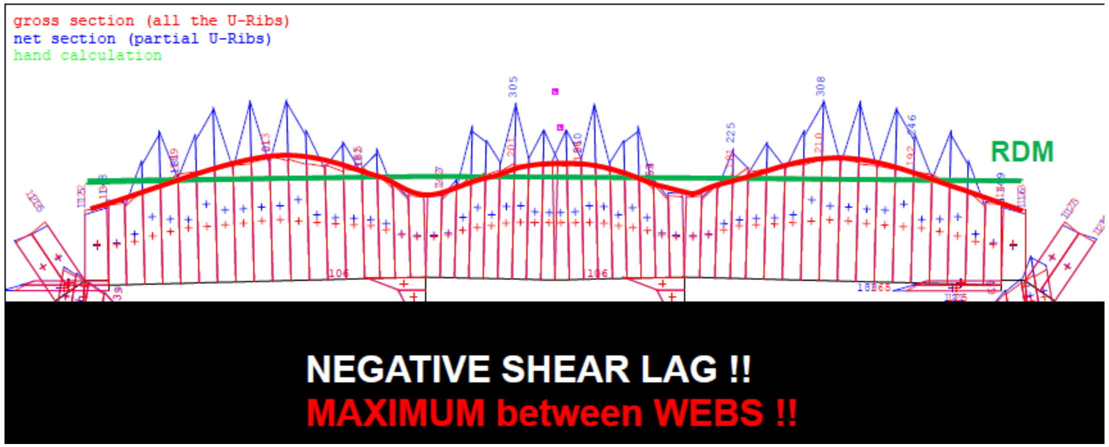


DERRICK CRANES

MINIMUM WELDING

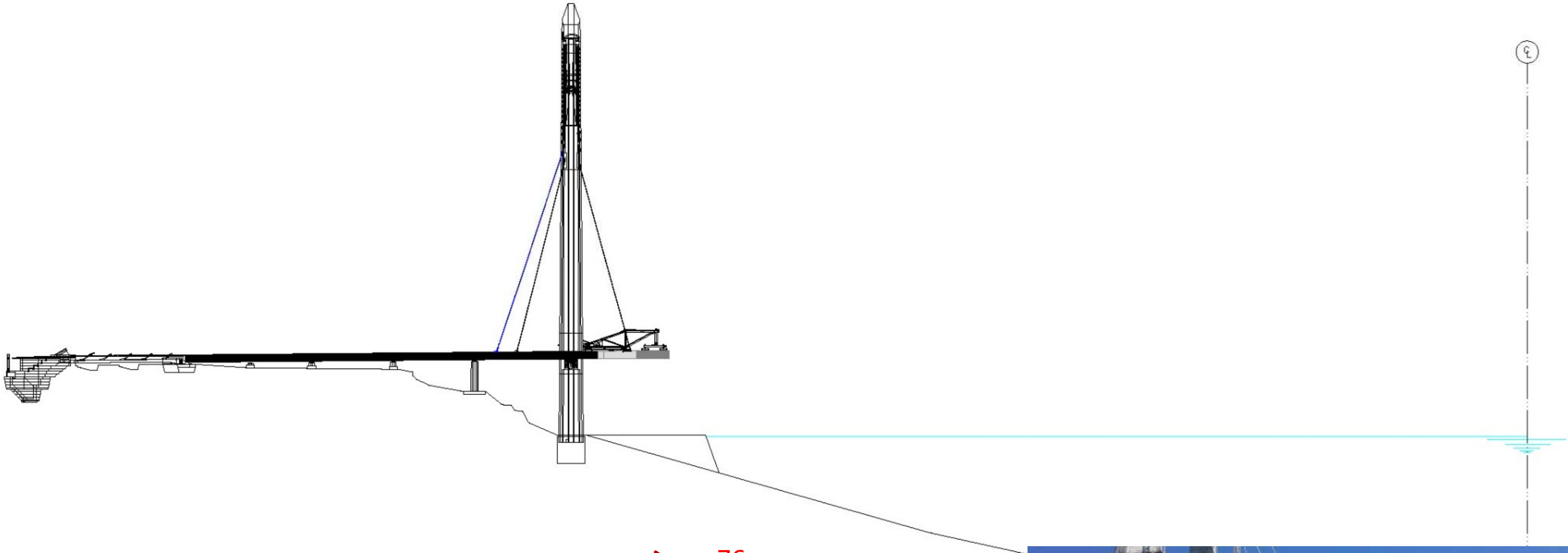






CANTILEVER
Segment D02 – 24 m

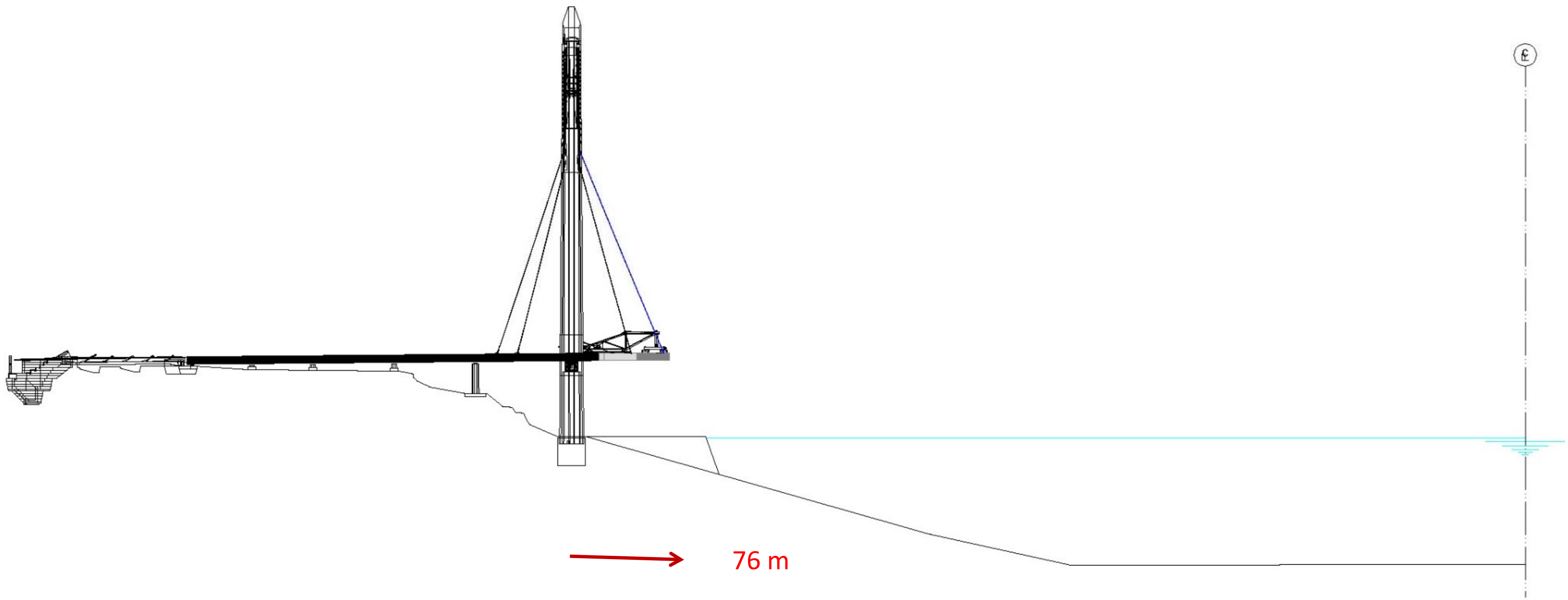
- Installation of stay cables S02B in the back span
- Release of segment D02, with only its weight



76 m

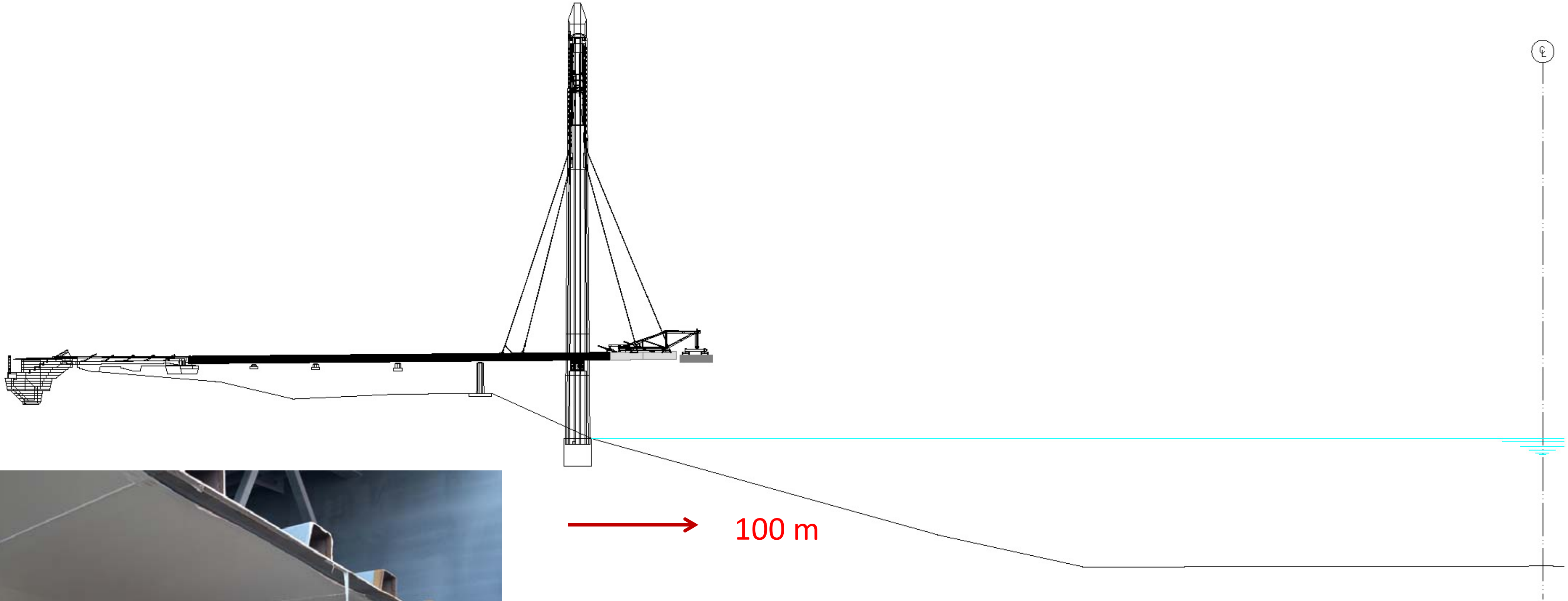
CANTILEVER
Segment D02 – 24 m

- Installation of stay cables S02M in the main span



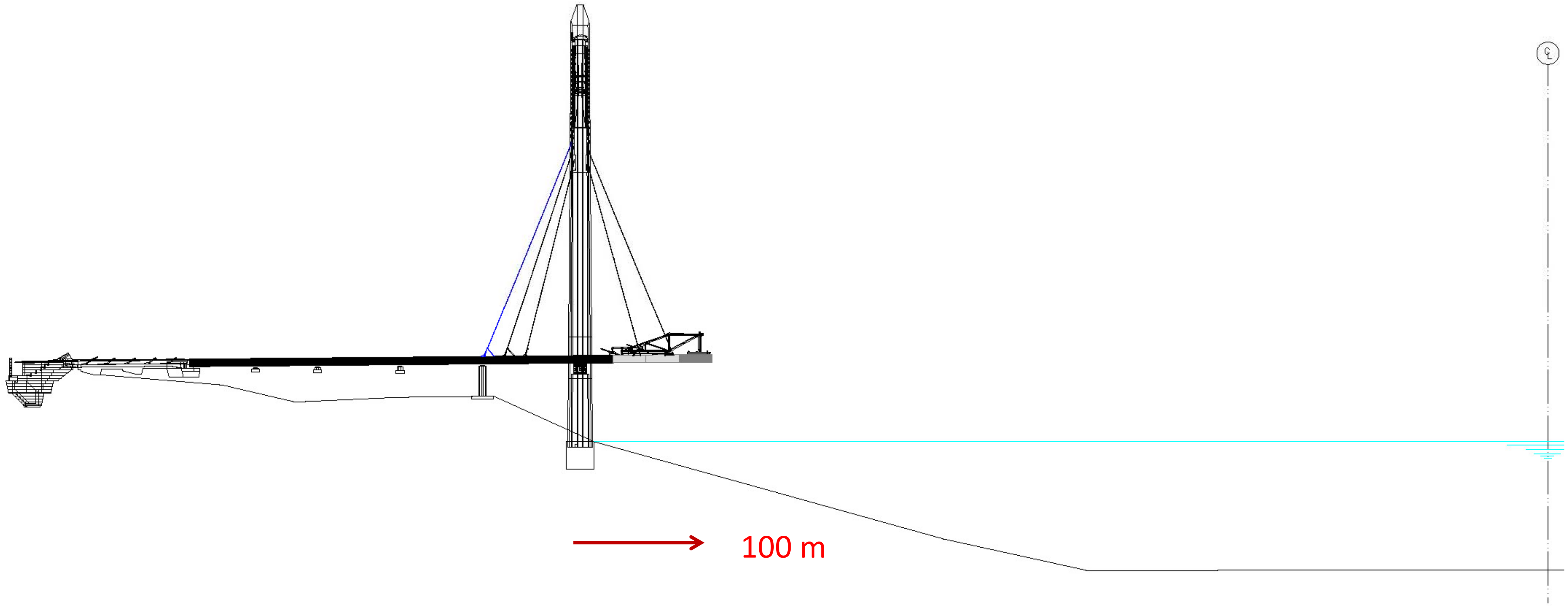
CANTILEVER
Segment D03 – 24 m

- Derrick cranes launching
- Erection of segment D03 (24 m) directly from the barge
- Welding connection between D02 and D03



CANTILEVER
Segment D03 – 24 m

- Installation of stay cables S03B in the back span
- Release of segment D03 with only its weight



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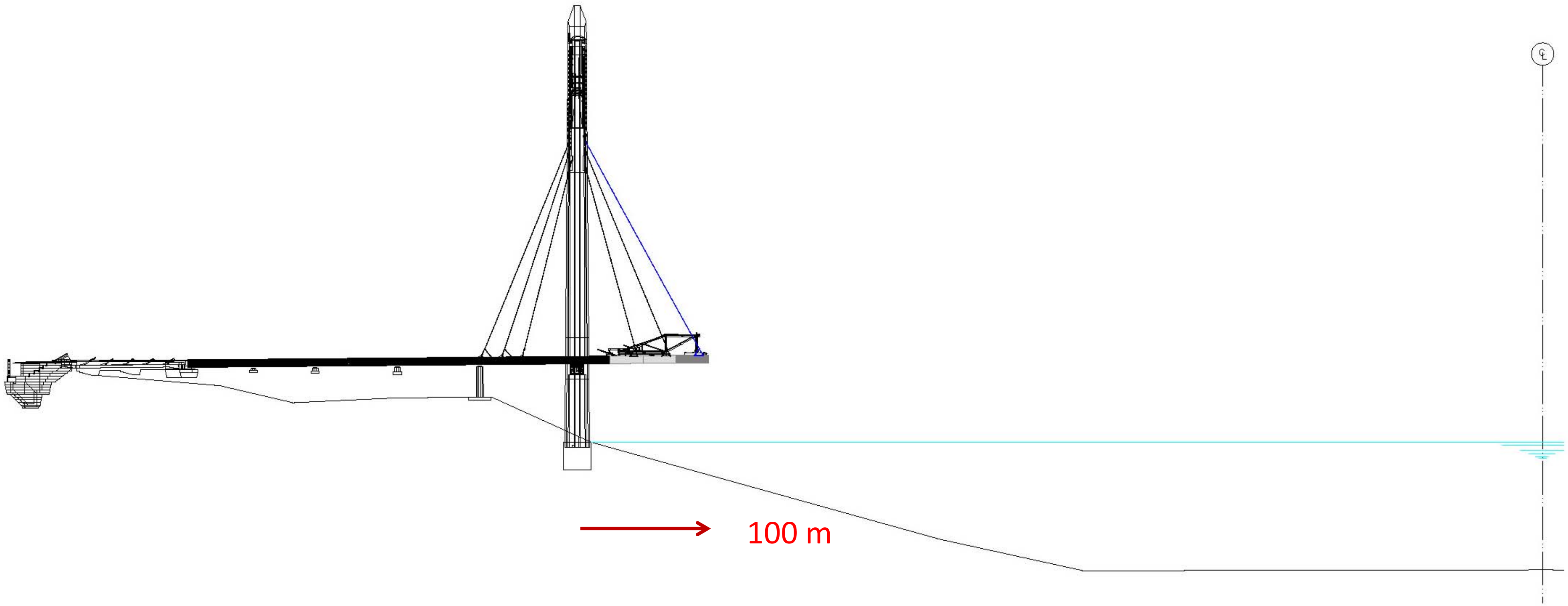
CANTILEVER
Segment D03 – 24 m

- Installation of stay cables S03M in the main span



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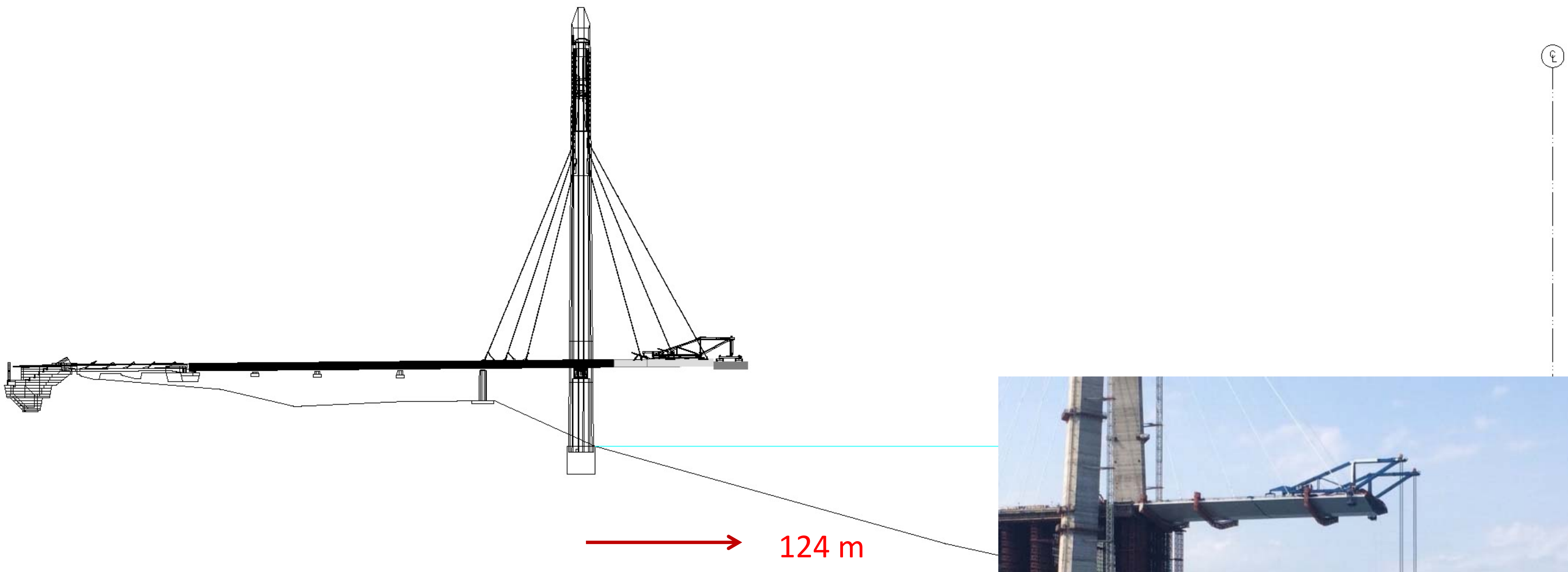
CANTILEVER
Segment D04 – 24 m

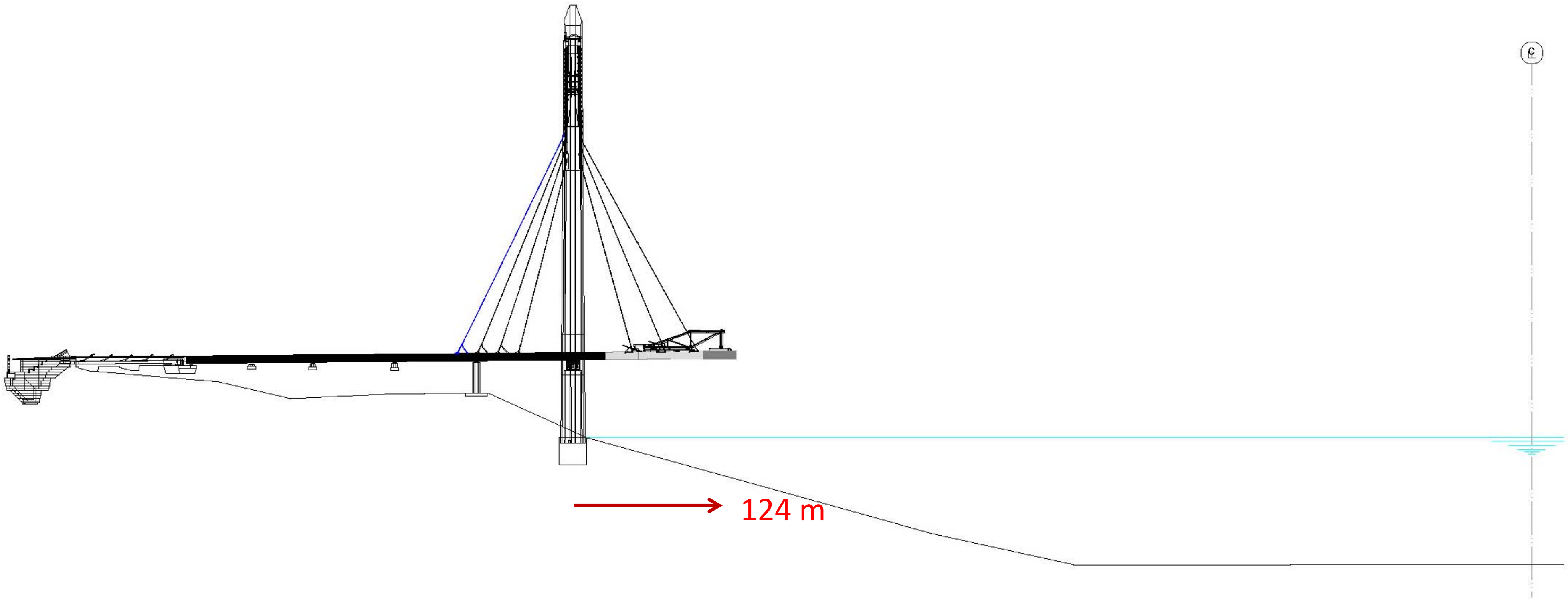
- Derrick cranes launching
- Erection of segment D04 (24 m) from the barge
- Welding connection between D03 and D04



ASTALDI

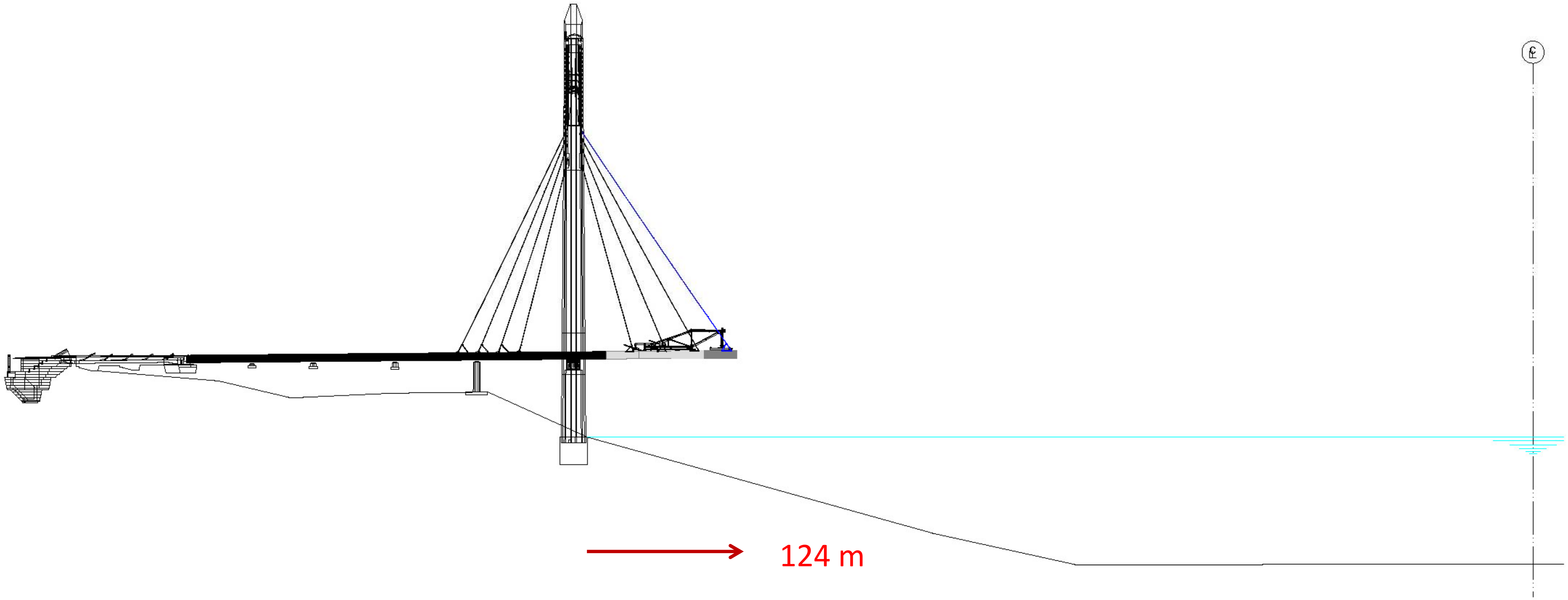
CANTILEVER
Segment D04 – 24 m

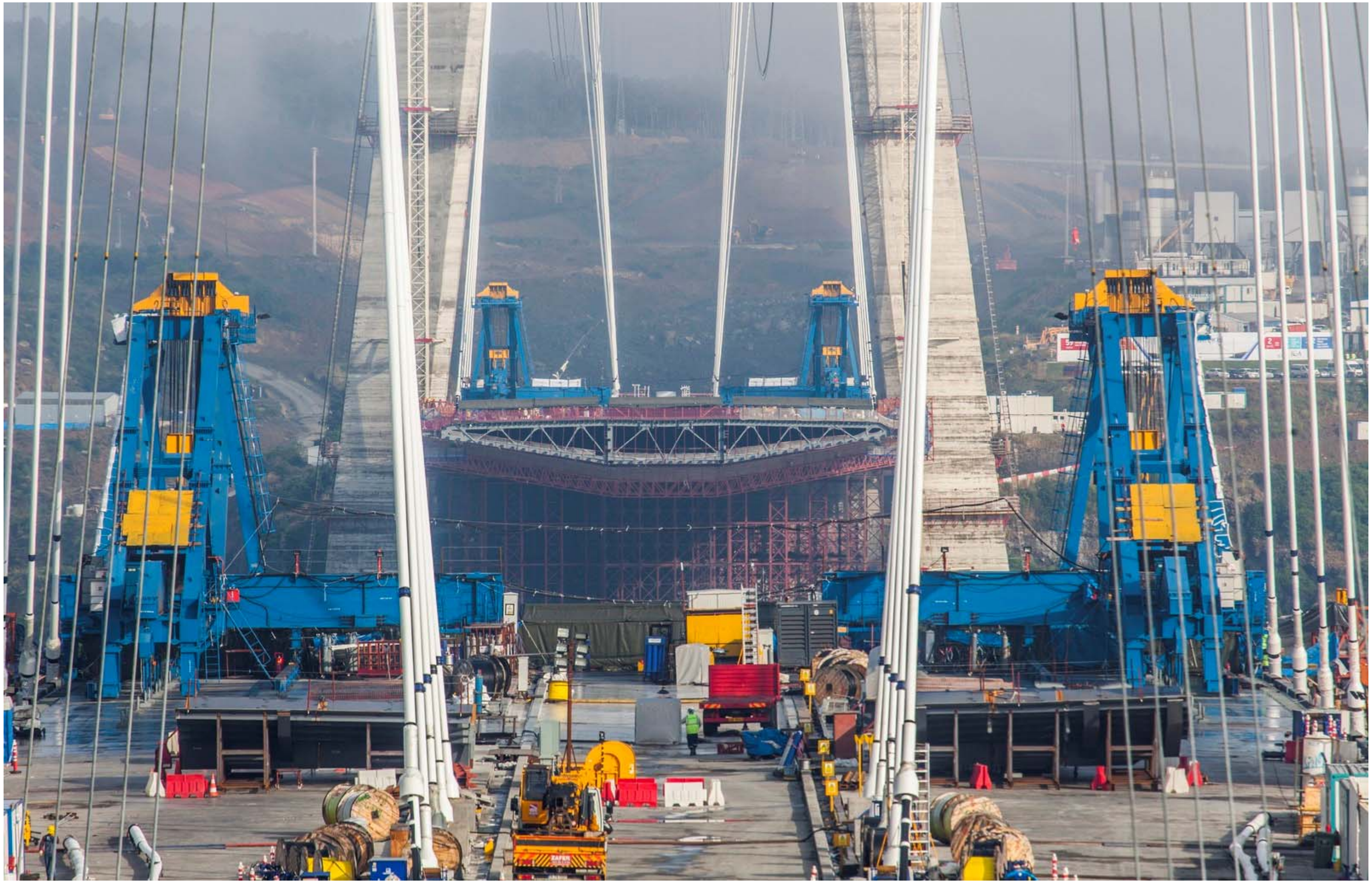
- Installation of stay cables S04B in the back span
- Release of segment D04 with only its weight



CANTILEVER
Segment D04 – 24 m

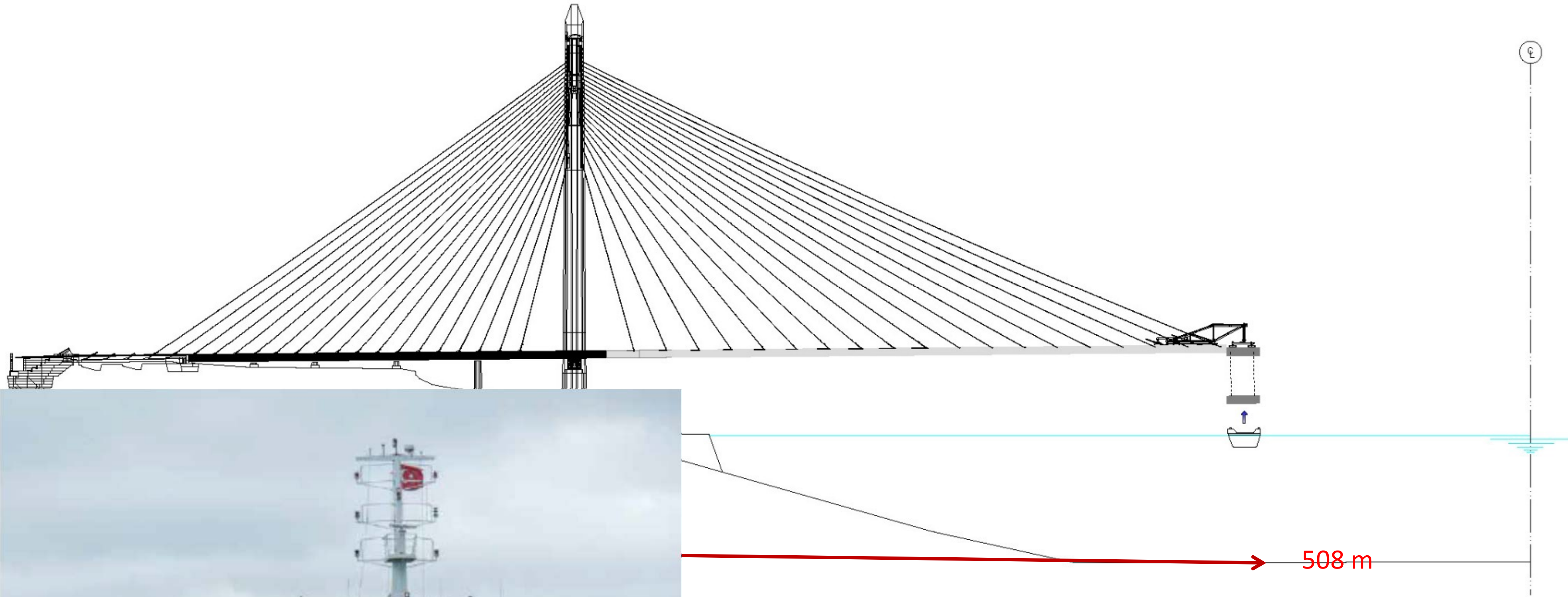
- Installation of stay cables S04M in the main span





CANTILEVER
Segment D20 – 24 m

- Derrick cranes launching
- Erection of segment D20 (24 m) from the barge
- Welding connection between D19 and D20



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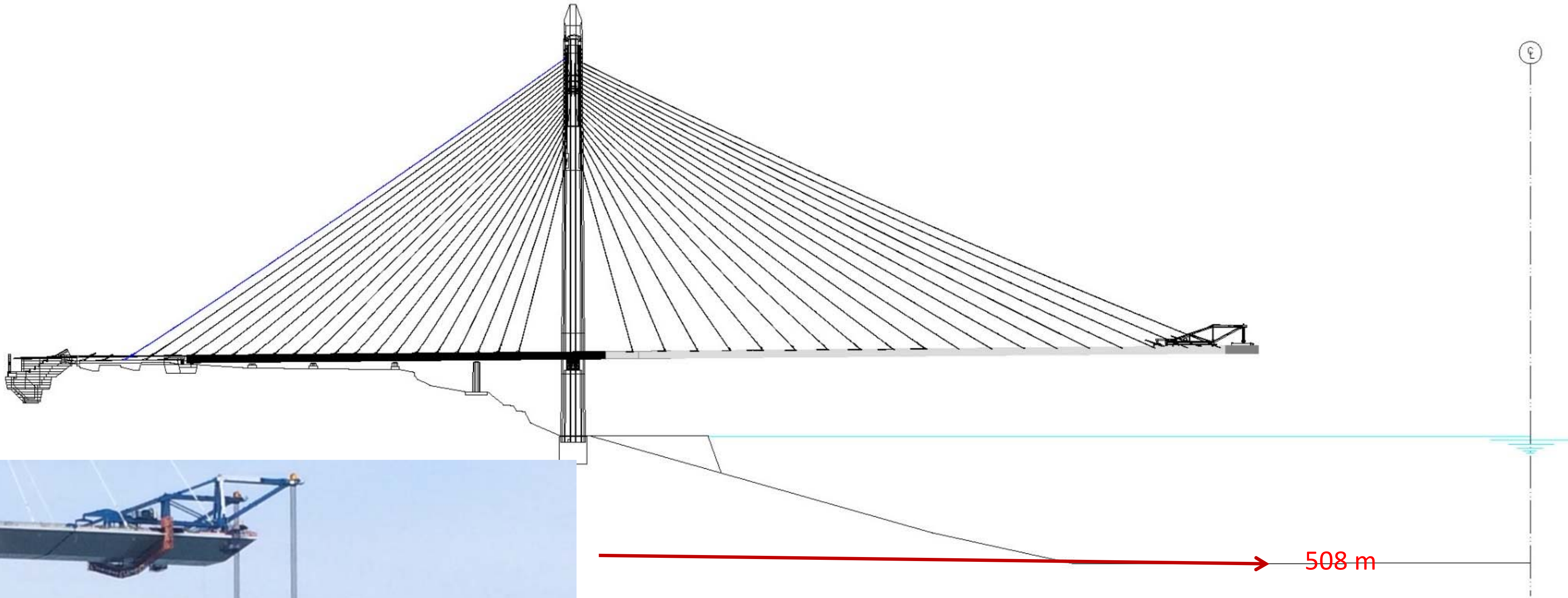
CANTILEVER
Segment D20 – 24 m

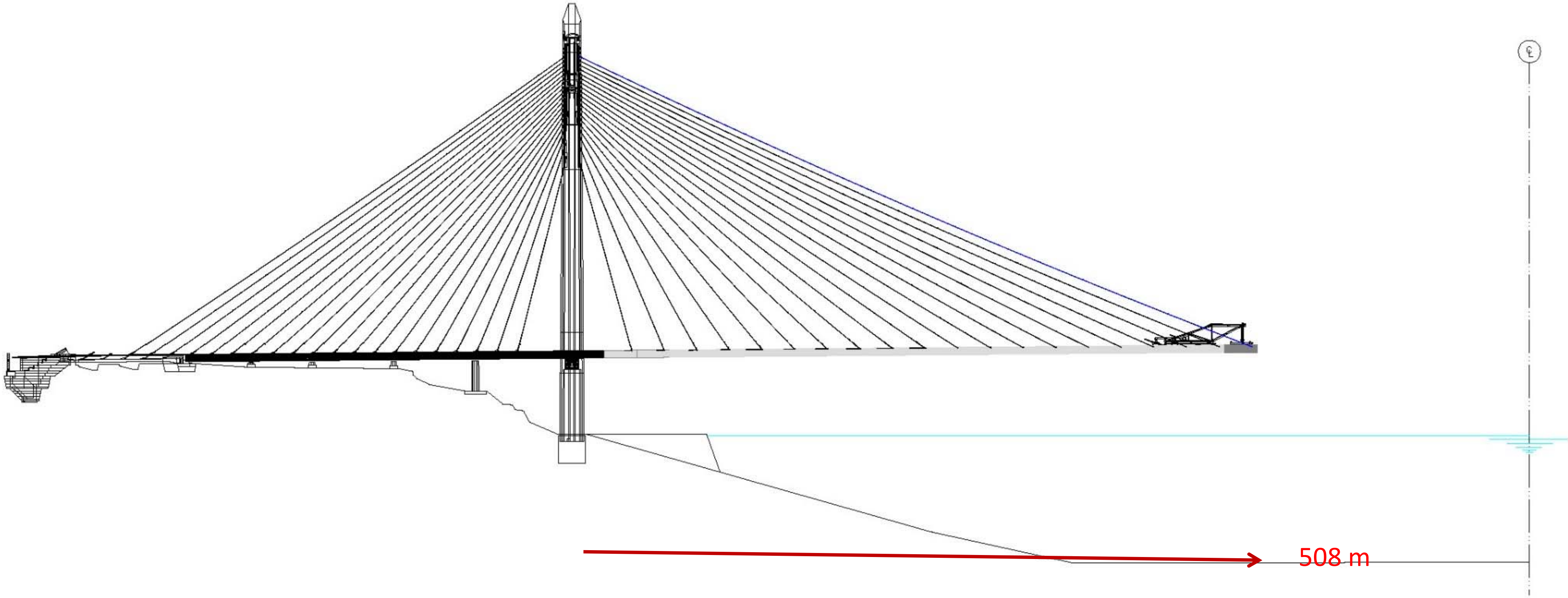
- Installation of stay cables S20B in the back span
- Release of segment D20 with only its weight



ASTALDI

CANTILEVER
Segment D20 – 24 m

- Installation of stay cables S20M in the main span



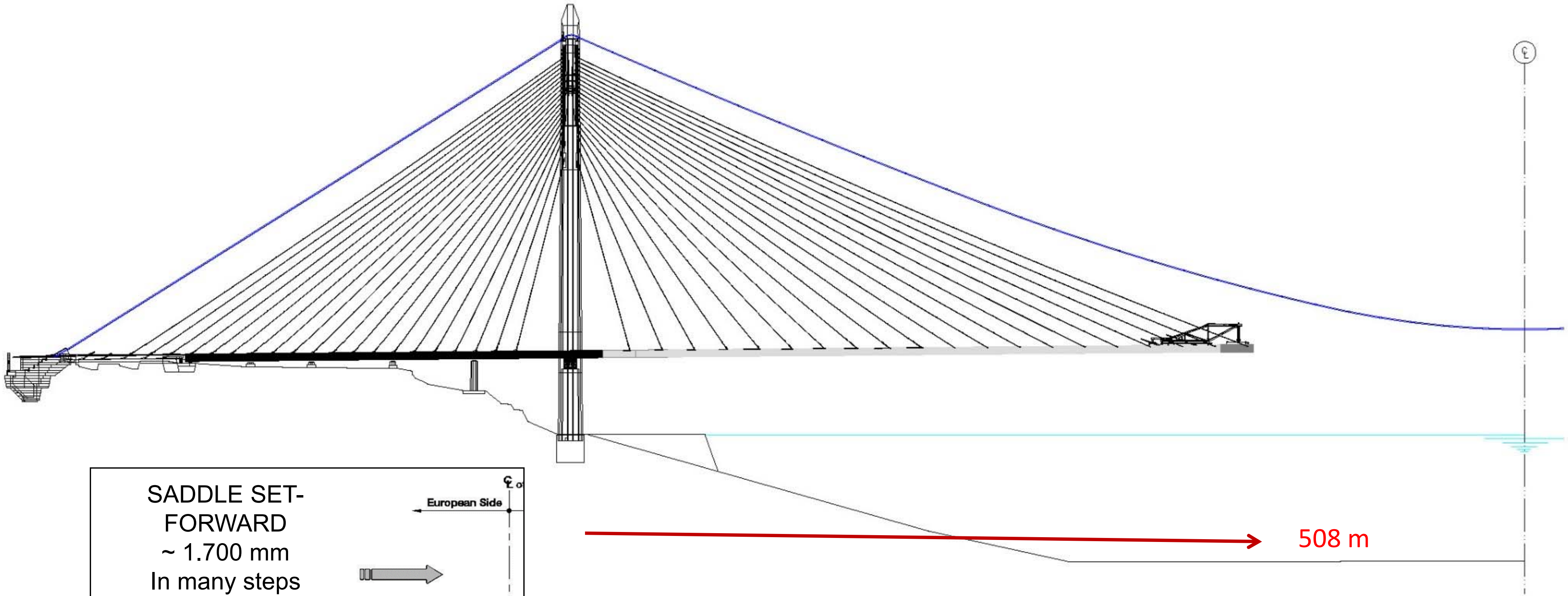
ASTALDI

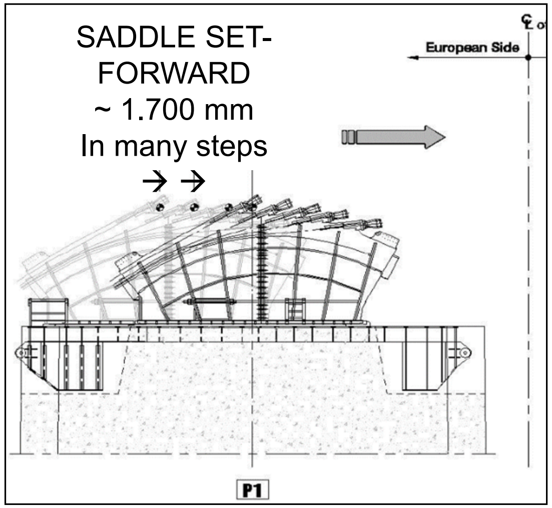
END OF CANTILEVER ERECTION PHASE

SUSPENDED PART

SUSPENDED PART

- Installation of the 2 main cables
- Disassembly of Derrick Crane
- Compaction of the 2 main cables
- Installation of the "cable bands"
- Shift of the Splay saddles



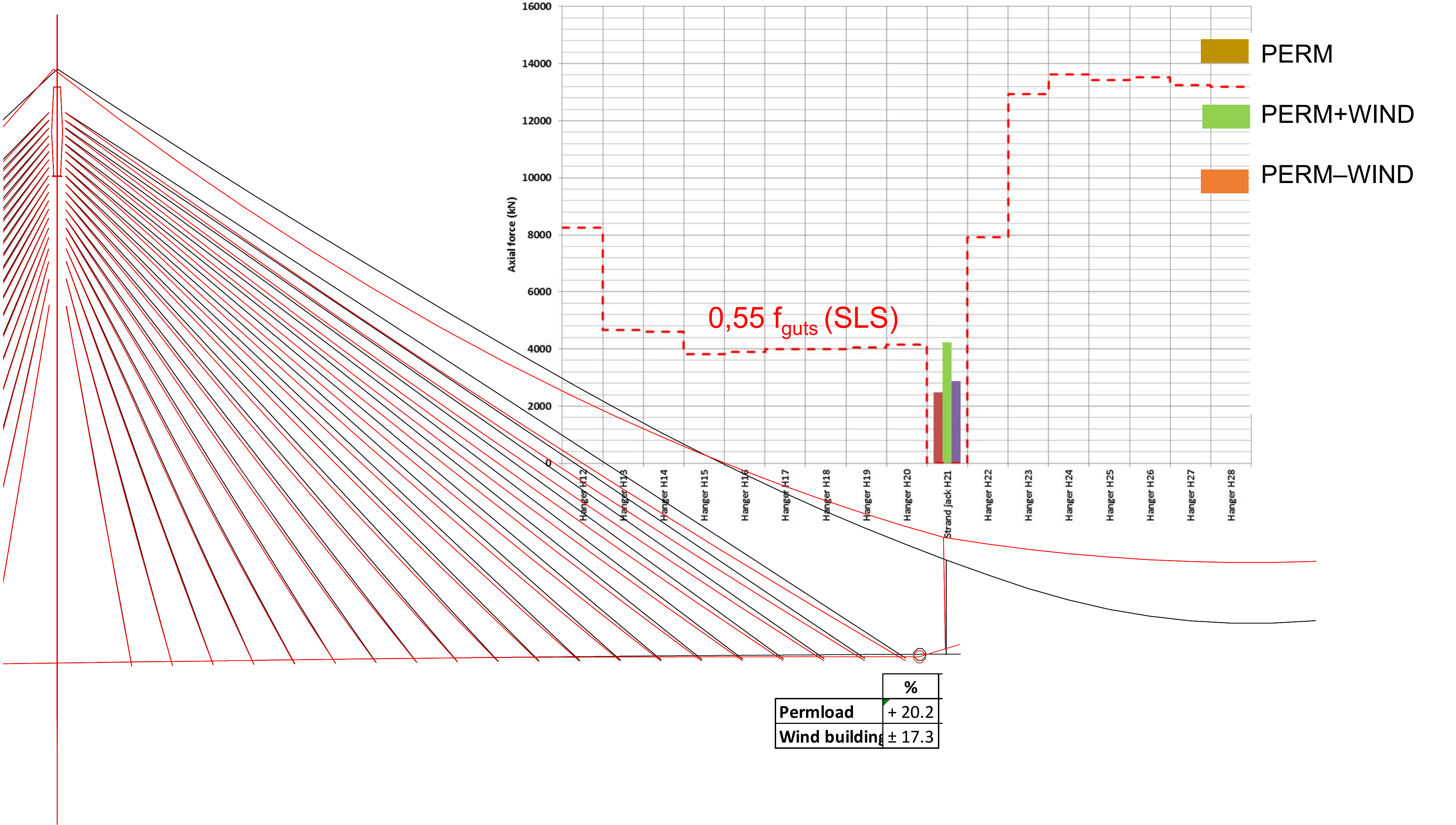


ASTALDI

MAIN CABLE POSITION

MAIN CABLE

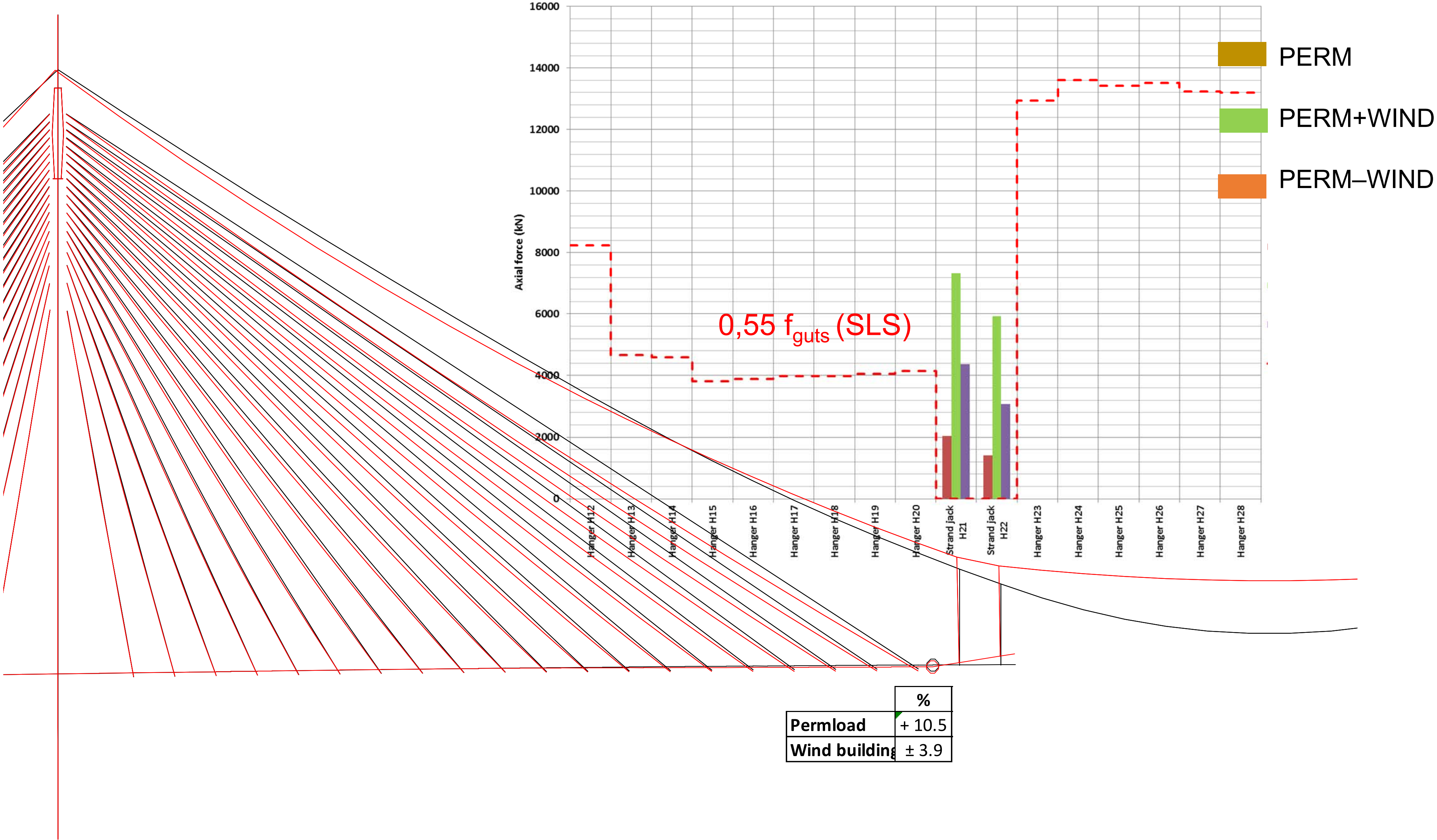
SHAPE AND POSITION



	%
Permload	+ 20.2
Wind building	± 17.3

MAIN CABLE

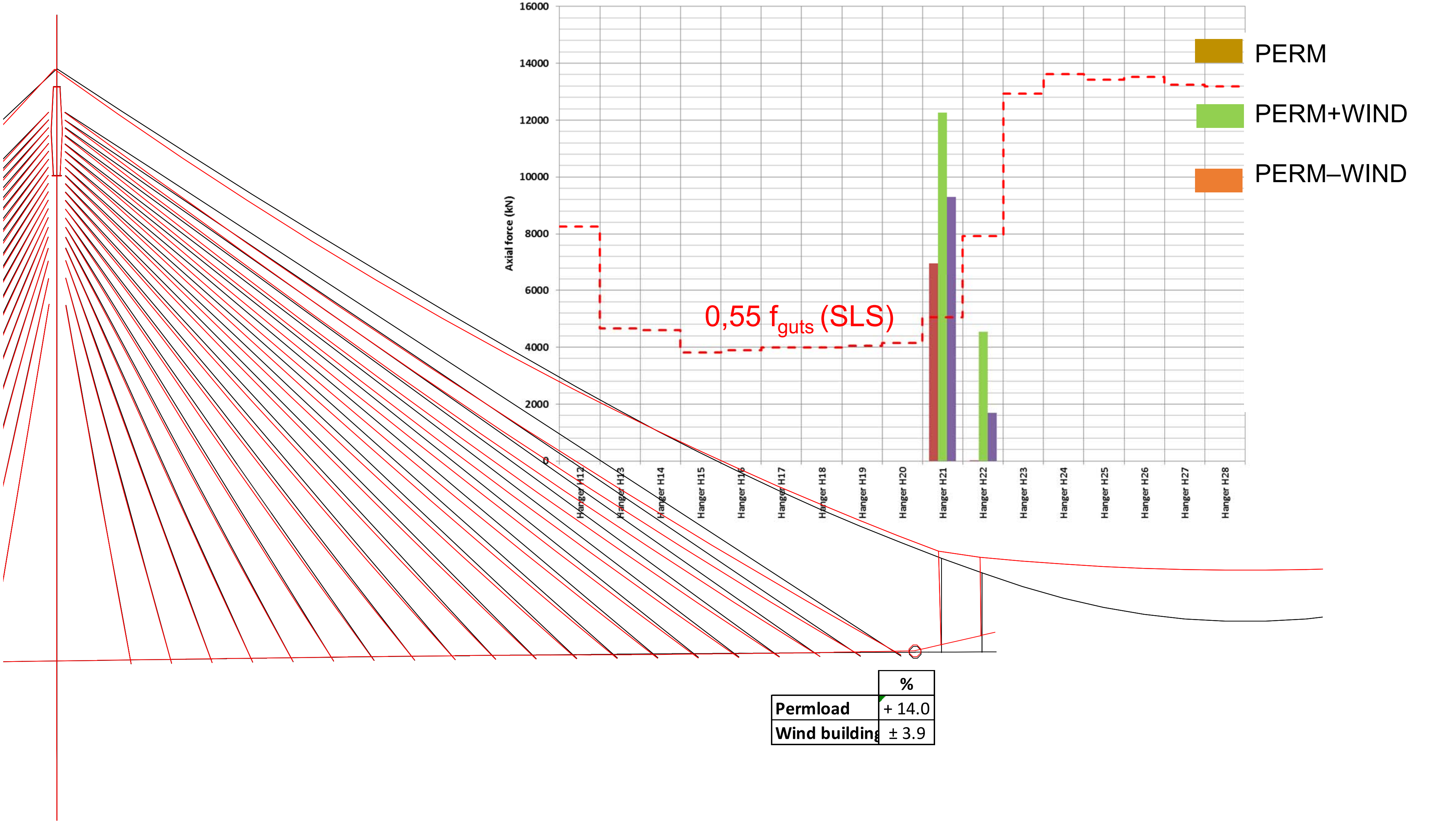
SHAPE AND POSITION



	%
Permload	+ 10.5
Wind building	± 3.9

MAIN CABLE

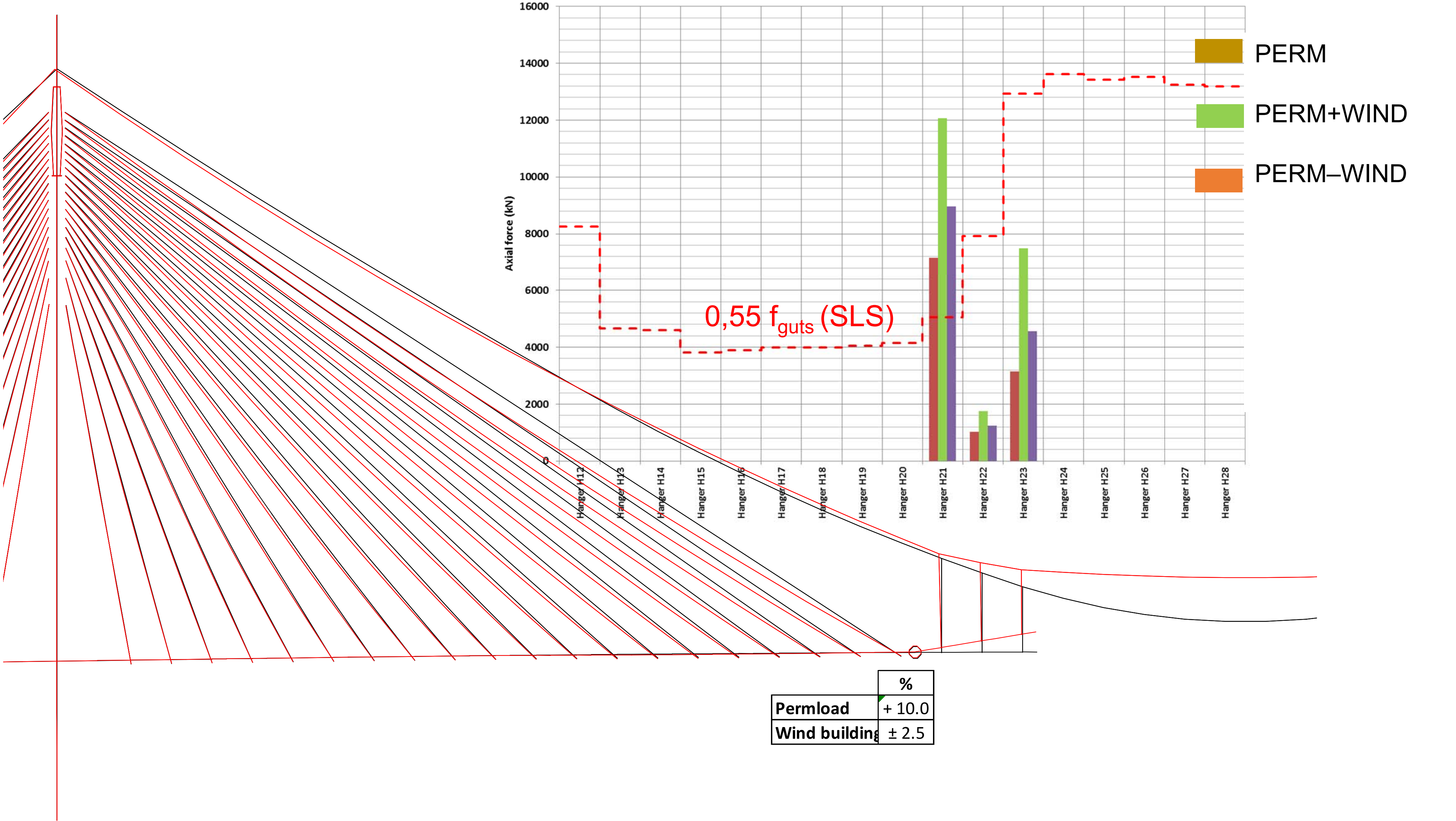
SHAPE AND POSITION



	%
Permload	+ 14.0
Wind building	± 3.9

MAIN CABLE

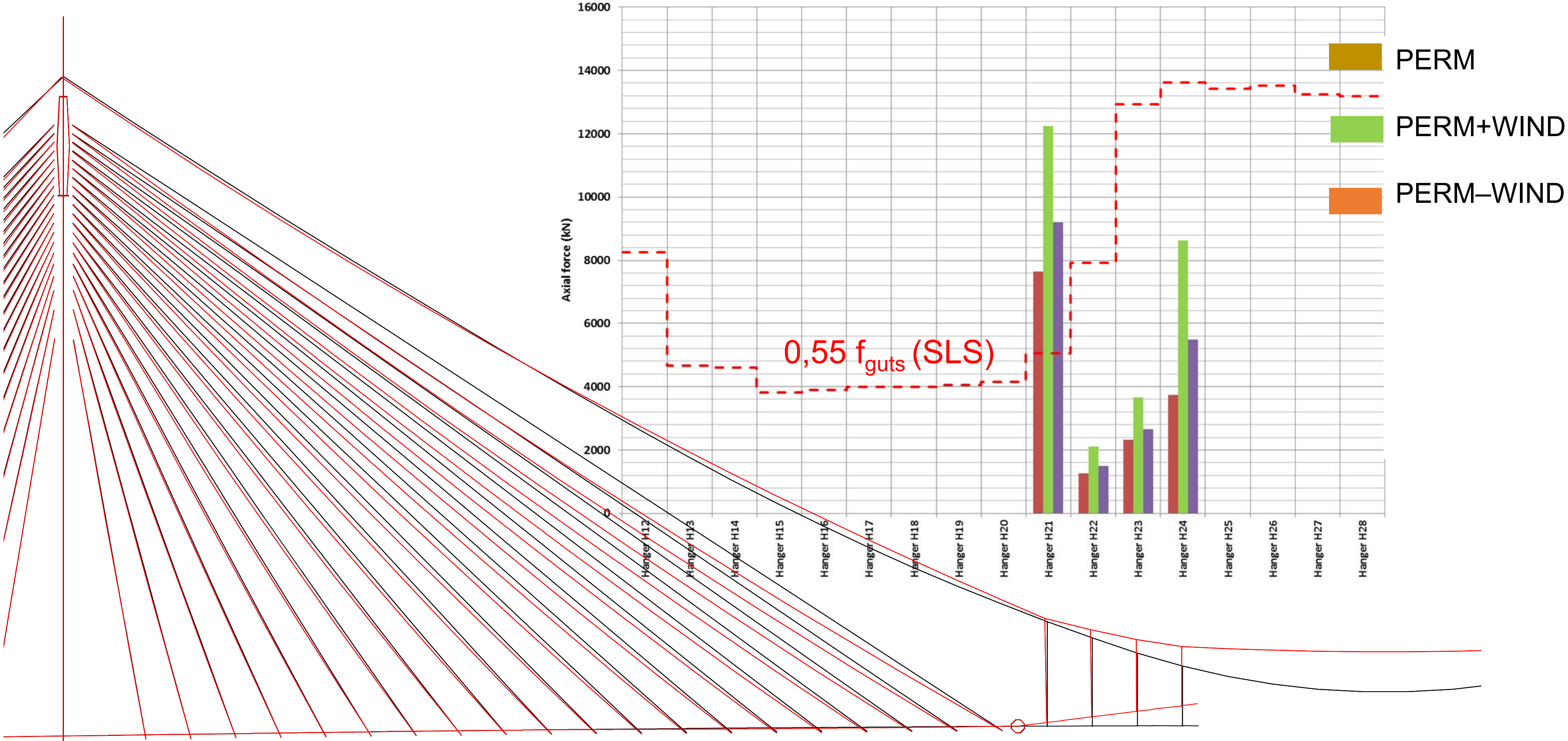
SHAPE AND POSITION



	%
Permload	+ 10.0
Wind building	± 2.5

MAIN CABLE

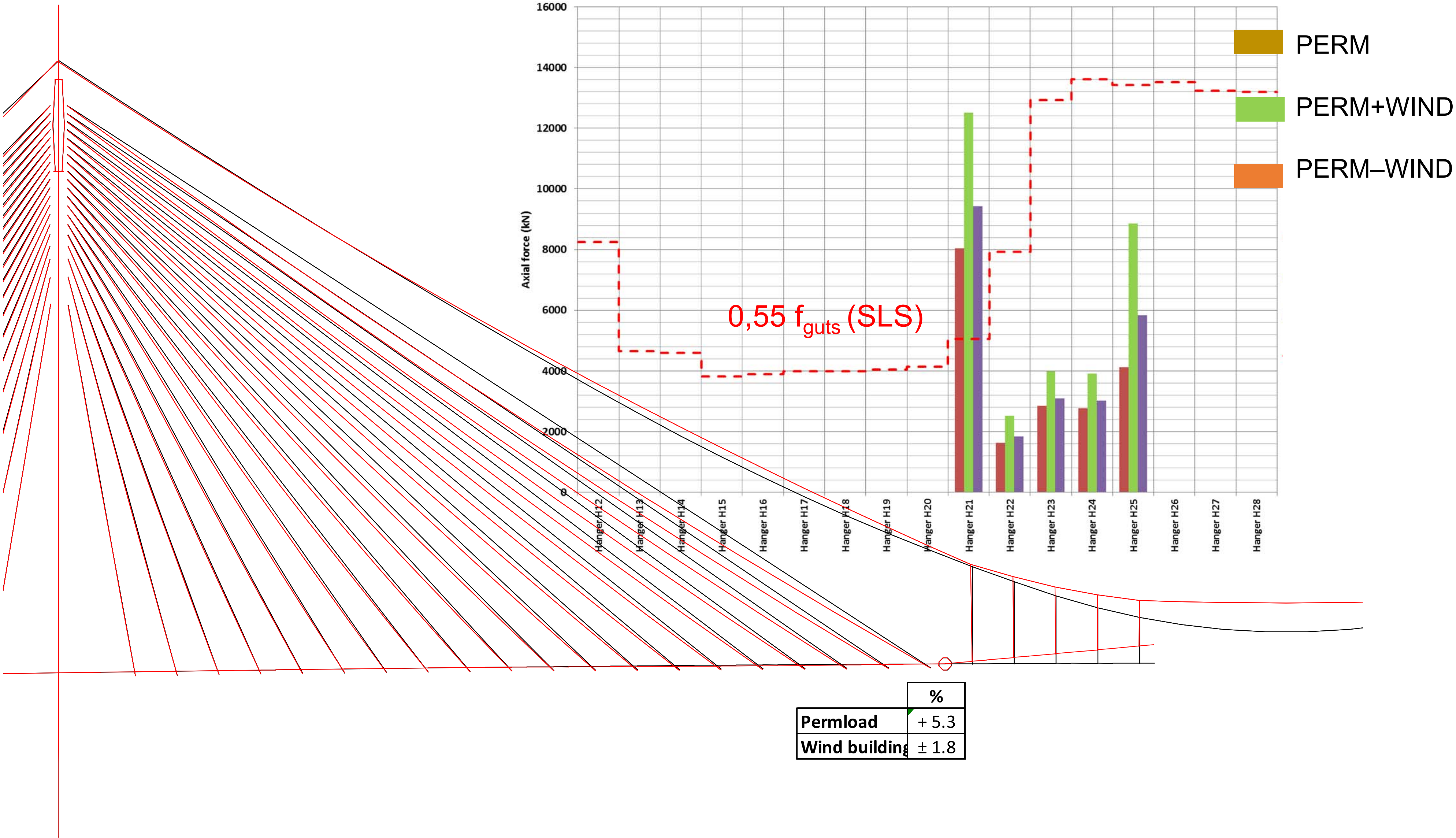
SHAPE AND POSITION



	%
Permload	+ 7.5
Wind building	± 2.0

MAIN CABLE

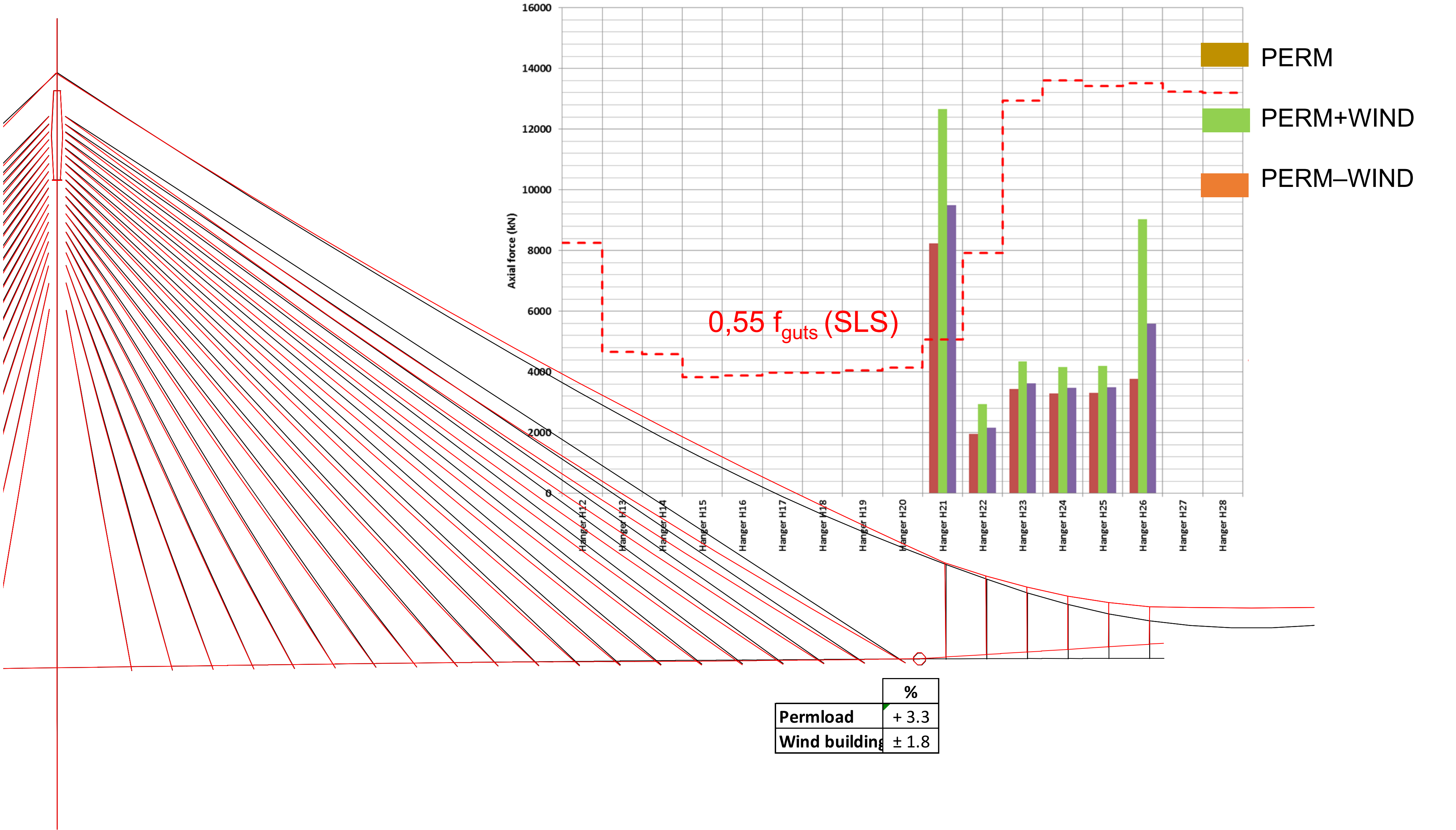
SHAPE AND POSITION



	%
Permload	+ 5.3
Wind building	± 1.8

MAIN CABLE

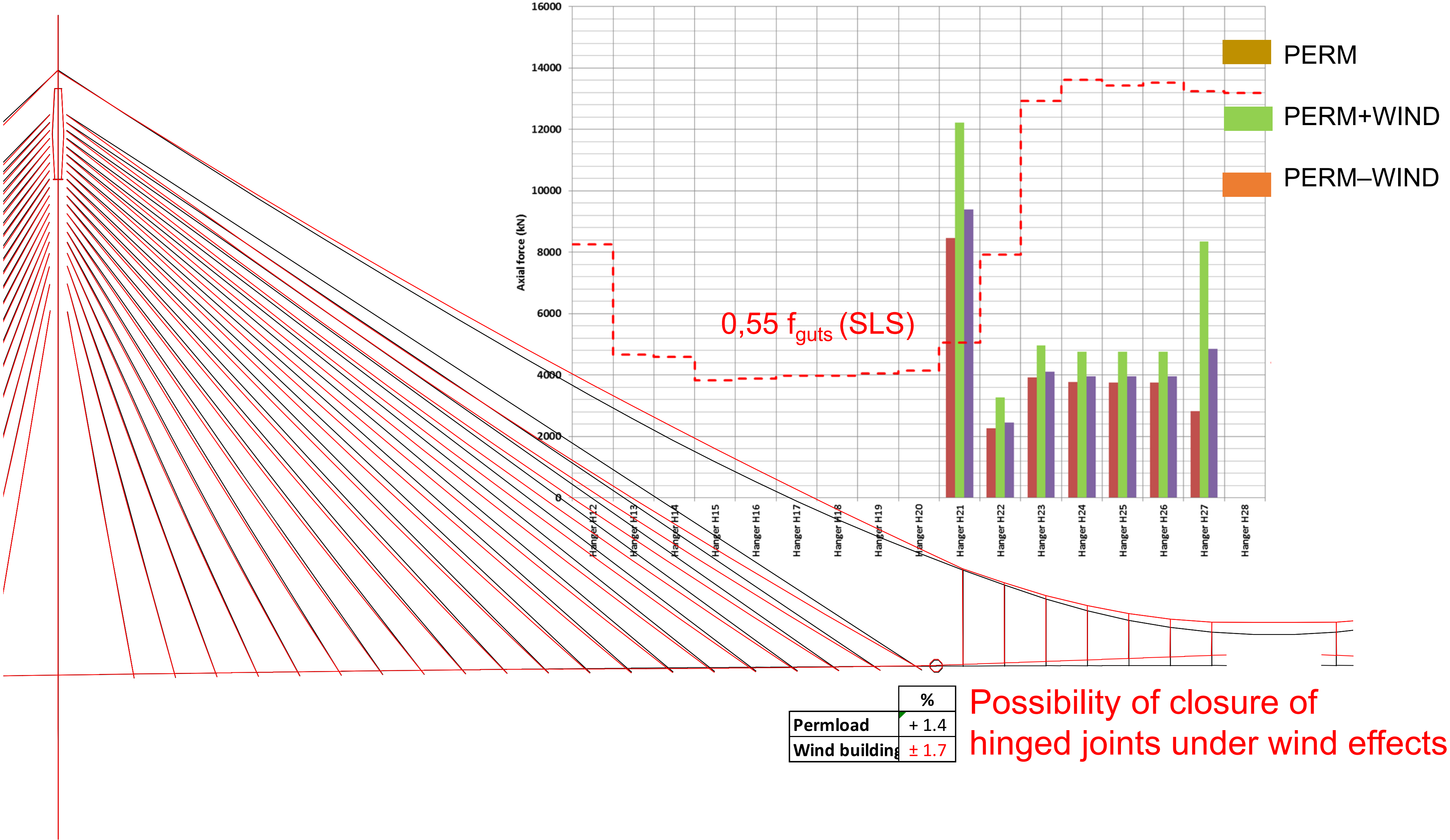
SHAPE AND POSITION



	%
Permload	+ 3.3
Wind building	± 1.8

MAIN CABLE

SHAPE AND POSITION

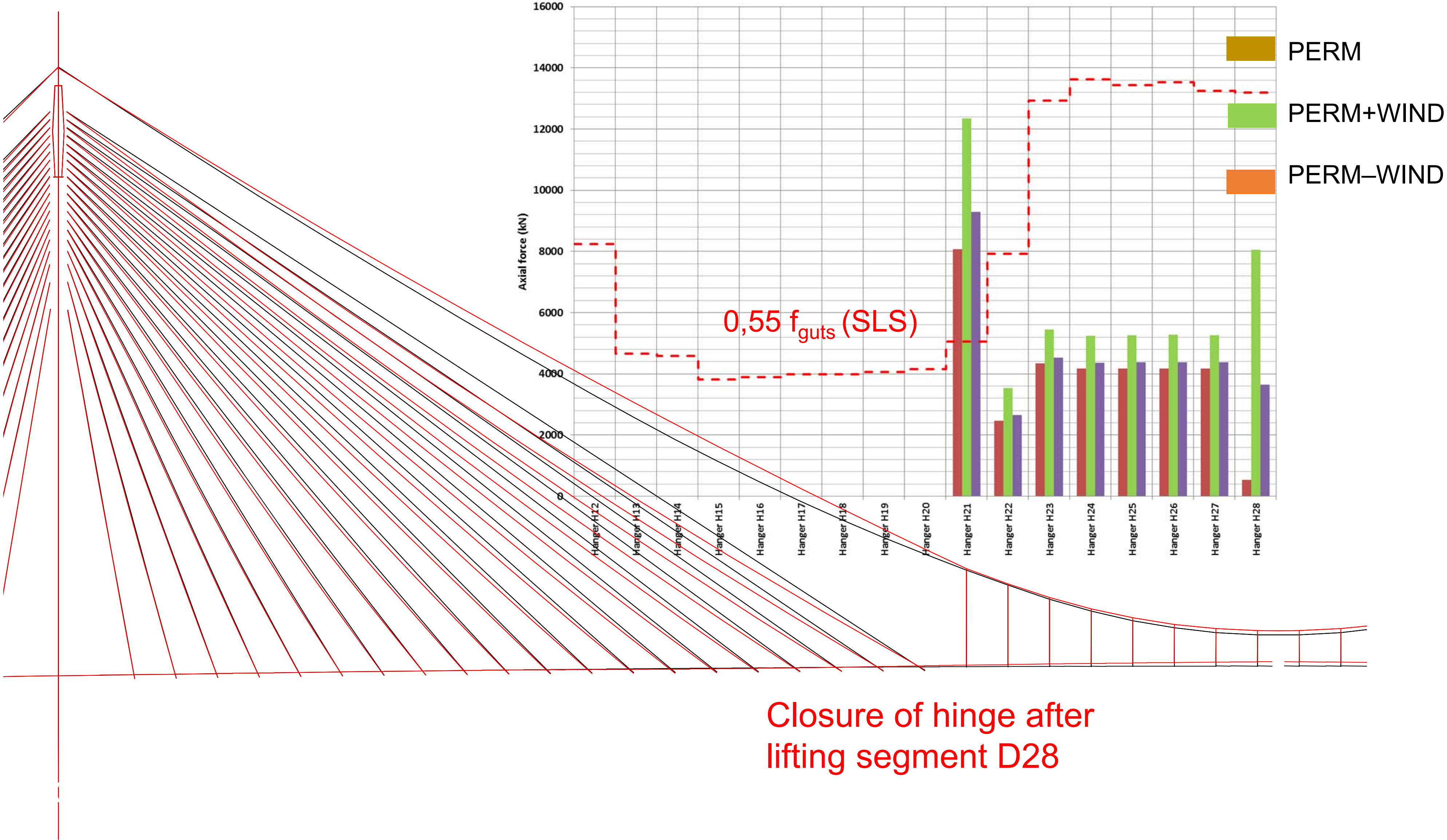


	%
Permload	+ 1.4
Wind building	± 1.7

Possibility of closure of hinged joints under wind effects

MAIN CABLE

SHAPE AND POSITION

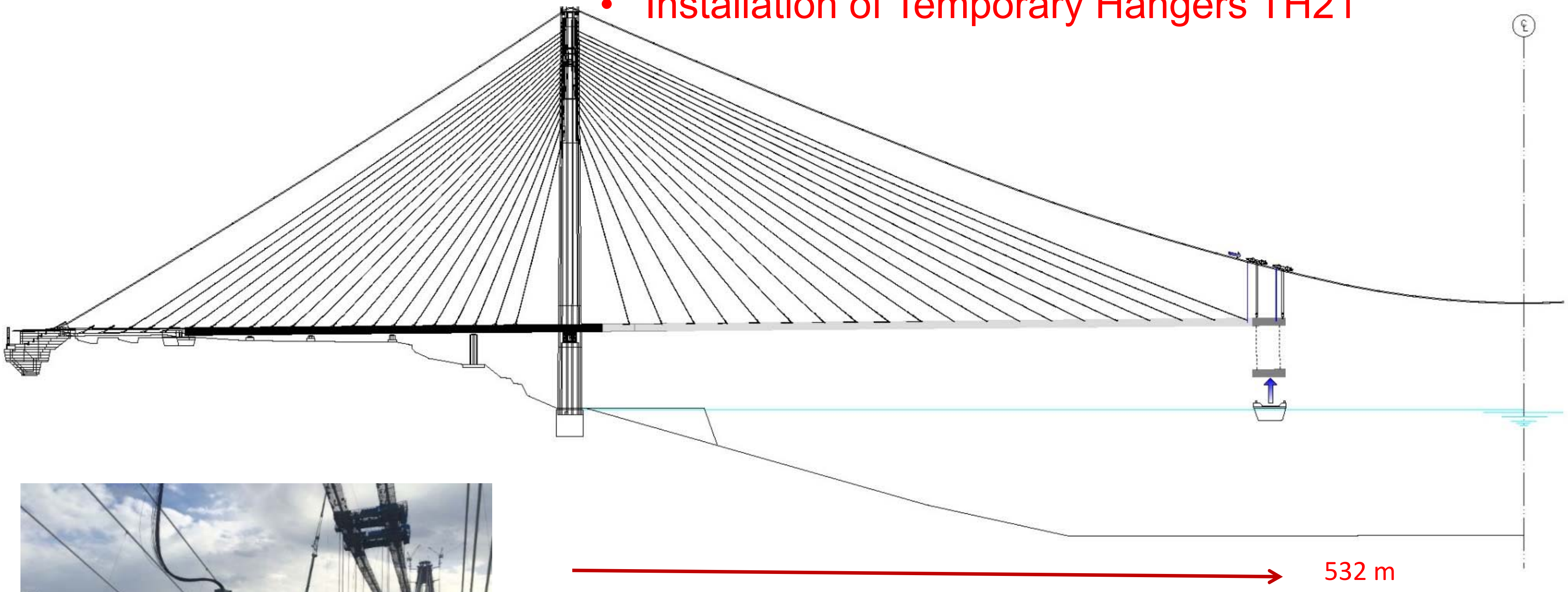


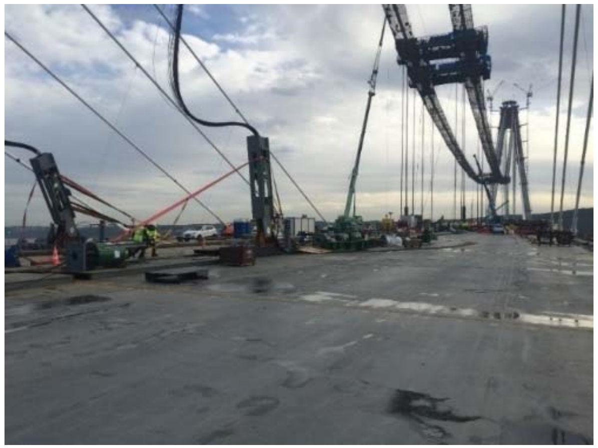
Closure of hinge after
lifting segment D28

SUSPENDED PART

SUSPENDED PART
Segment D21 – 24 m

- Installation of lifting gantry
- Shifting of the Splay saddles
- Installation of the Temporary hangers TH20
- Shifting of the Splay saddles
- Erection of segment D21
  - Adjustment of the length of Temporary hangers TH20
  - Welding between D20 and D21
  - Installation of Temporary Hangers TH21





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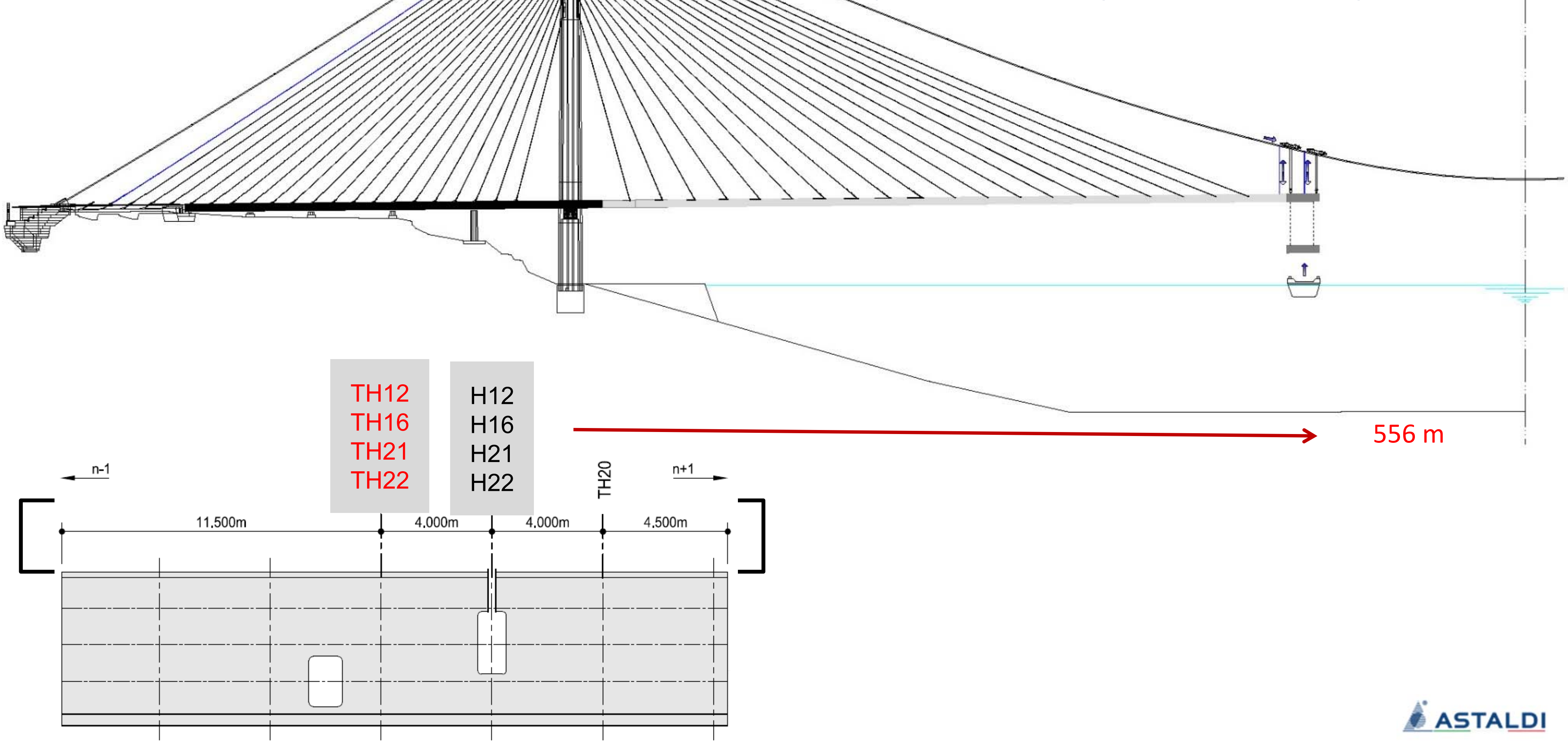
SUSPENDED PART
Segment D22 – 24 m

- Shifting lifting gantry
- Removal of Temporary gantries TH20
- Erection of segment D22
- Welding between D21e D22
    - Shifting of Splay saddles
    - Installation of Hangers S21B (back span)
    - Installation of Temporary hangers TH22
        - Adjustment length Temp. hangers TH21 e TH22
        - Shifting Saddles
            - Adjustment length Temp. hangers TH21/TH22



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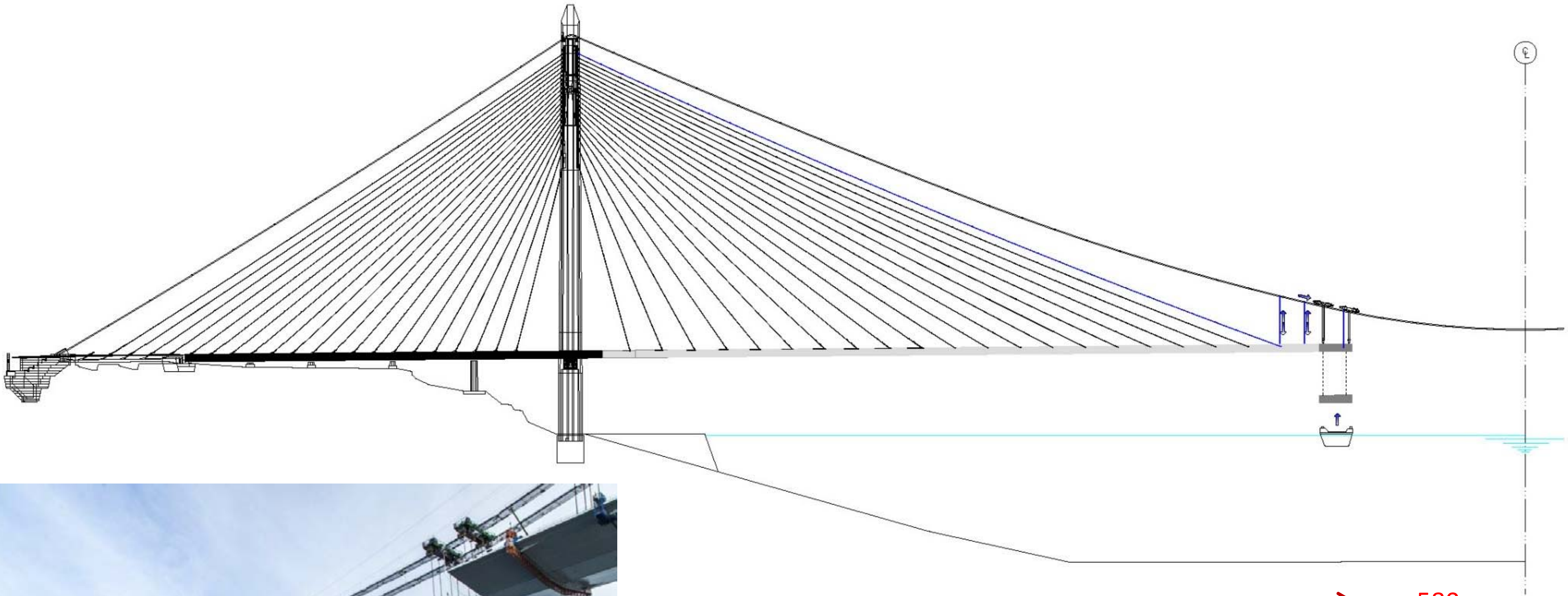
SUSPENDED PART
Segment D23 – 24 m

- Erection segment D23
- Welding between segment D22 and D23
- Installation of stay cable S21M main span
- Installation Temporary hangers H23
- Shifting of the Saddles

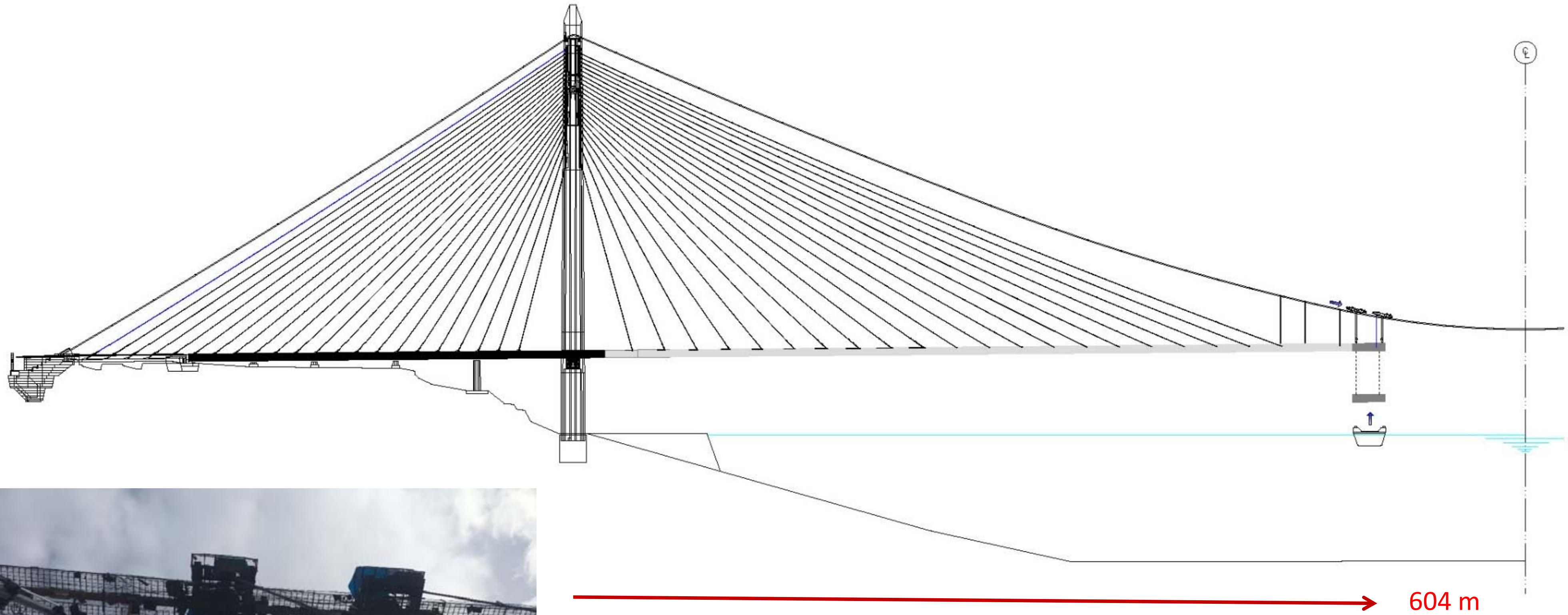


580 m

ASTALDI

SUSPENDED PART
Segment D24 – 24 m

- Erection segment D24
- Welding between segment D23 and D24
- Installation stay cables S22B back span
- Adjustment length Temporary hangers TH21/ TH22
- Installation hangersH24
- Shifting of the Saddles



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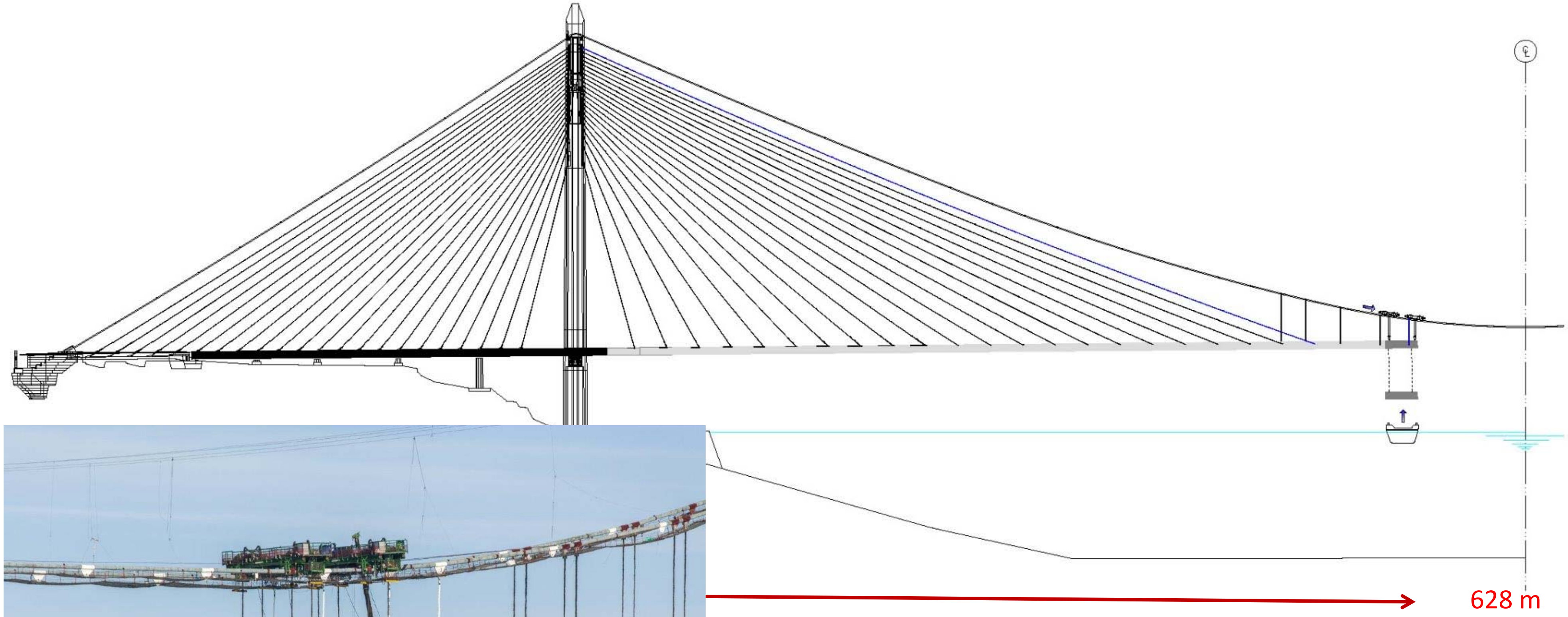
SUSPENDED PART
Segment D25 – 24 m

- Erection segment D25
- Welding between segments D24 and D25
- Installation stay cables S22M main span
- Installation hangers H25



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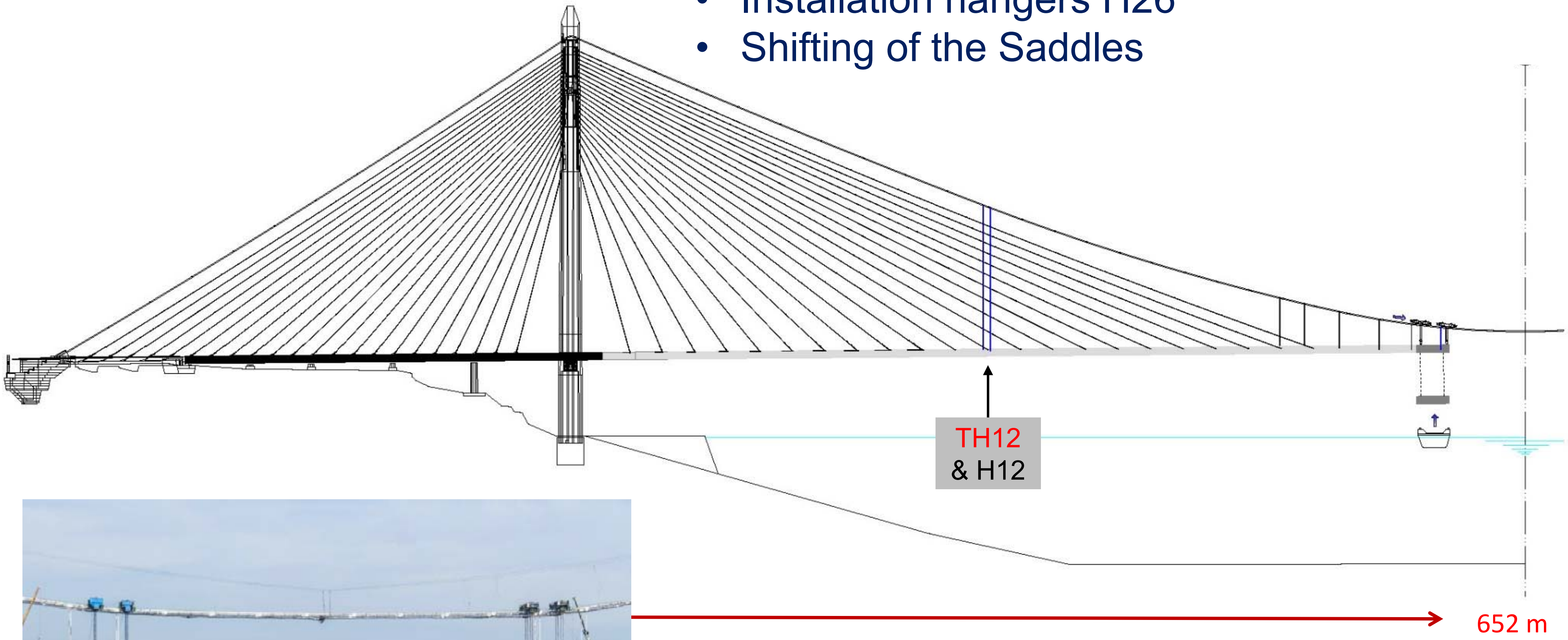
SUSPENDED PART
Segment D26 – 24 m

- Erection segment D26
- Welding between segment D25 and D26
- Shifting Saddles
- Installation Temporary hangers TH12
- Installation hangers H12
- Removal temporary hangers TH12
- Installation hangers H26
- Shifting of the Saddles



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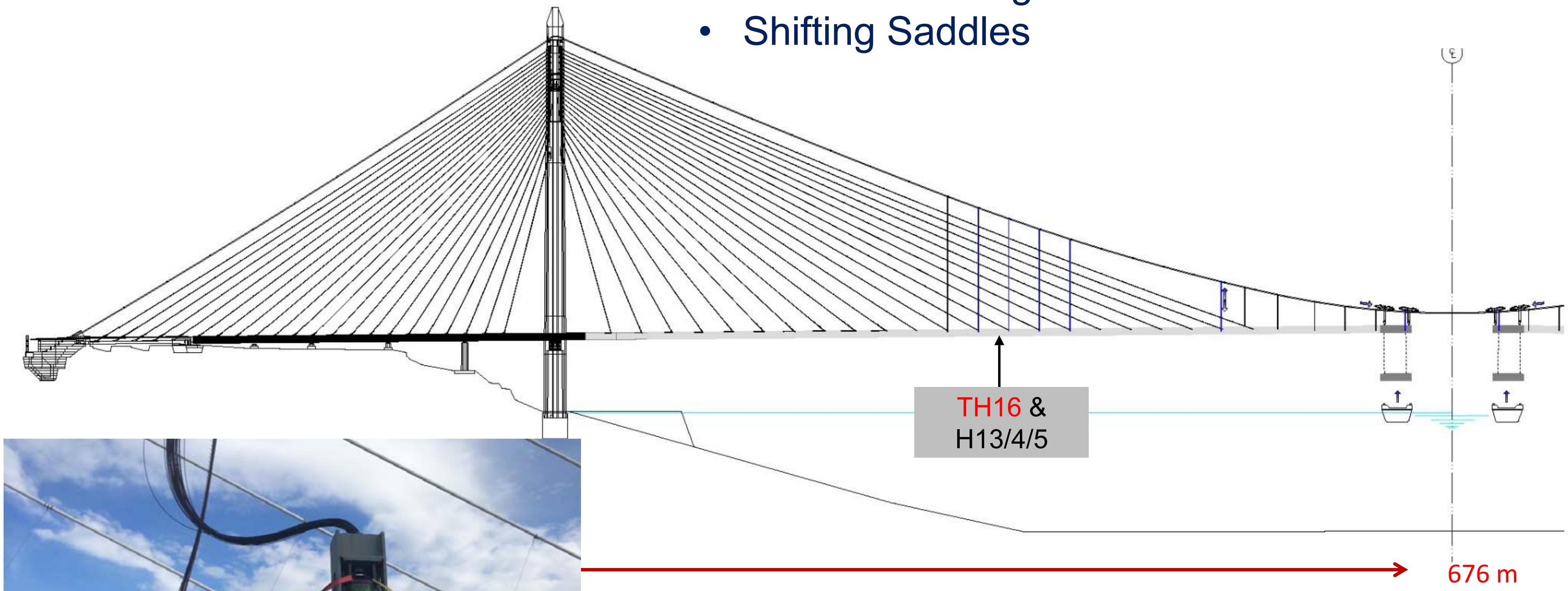
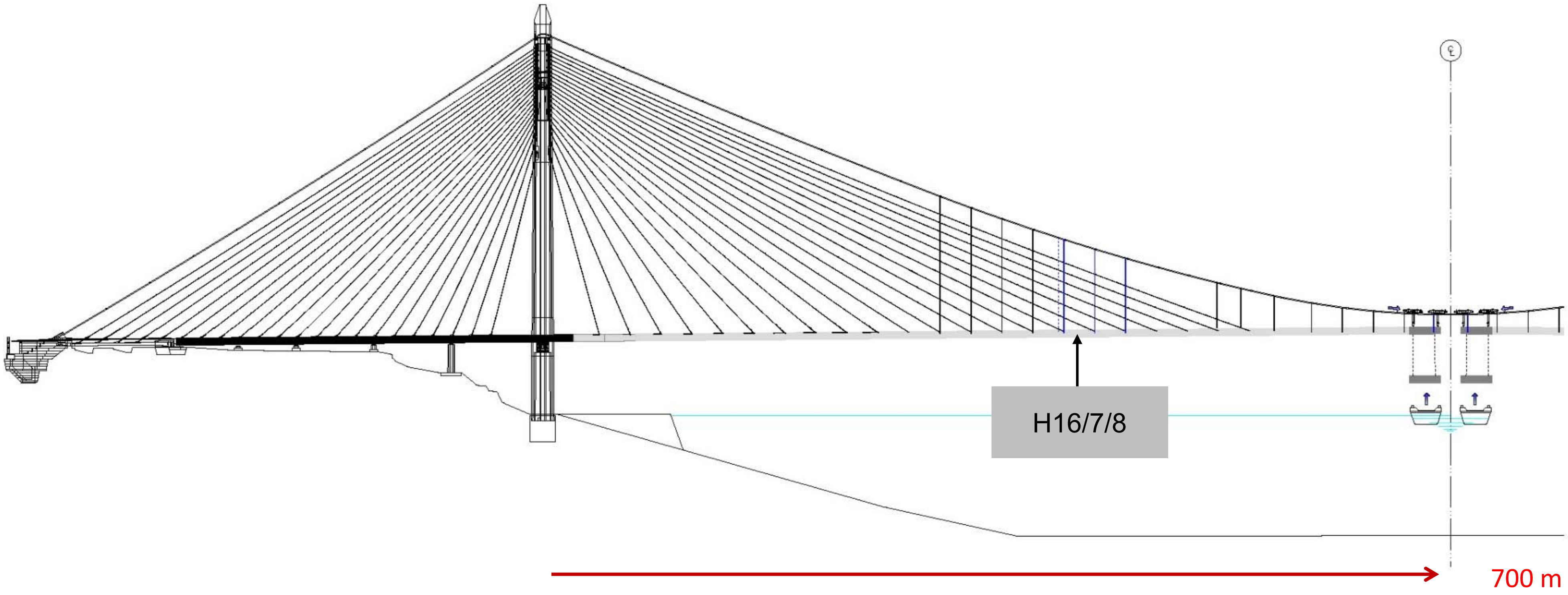
SUSPENDED PART
Segment D27 – 24 m

- Erection segment D27
- Welding between segment D26 and D27
- Shifting Saddles
- Installation Temporary hangers TH16
- Adjustment length Temporary hangers TH21
- Installation hangers H13 / H14 / H15
- Installation hangers H27
- Shifting Saddles



SUSPENDED PART
Segment D27 – 24 m

- Erection segment D28
- Welding between segment D27 and D28
- Shifting Saddles
- Installation hangers H17 / H18 / H16
- Removal Temporary hangers TH16
- Installation hangers H28
- Shifting Saddles



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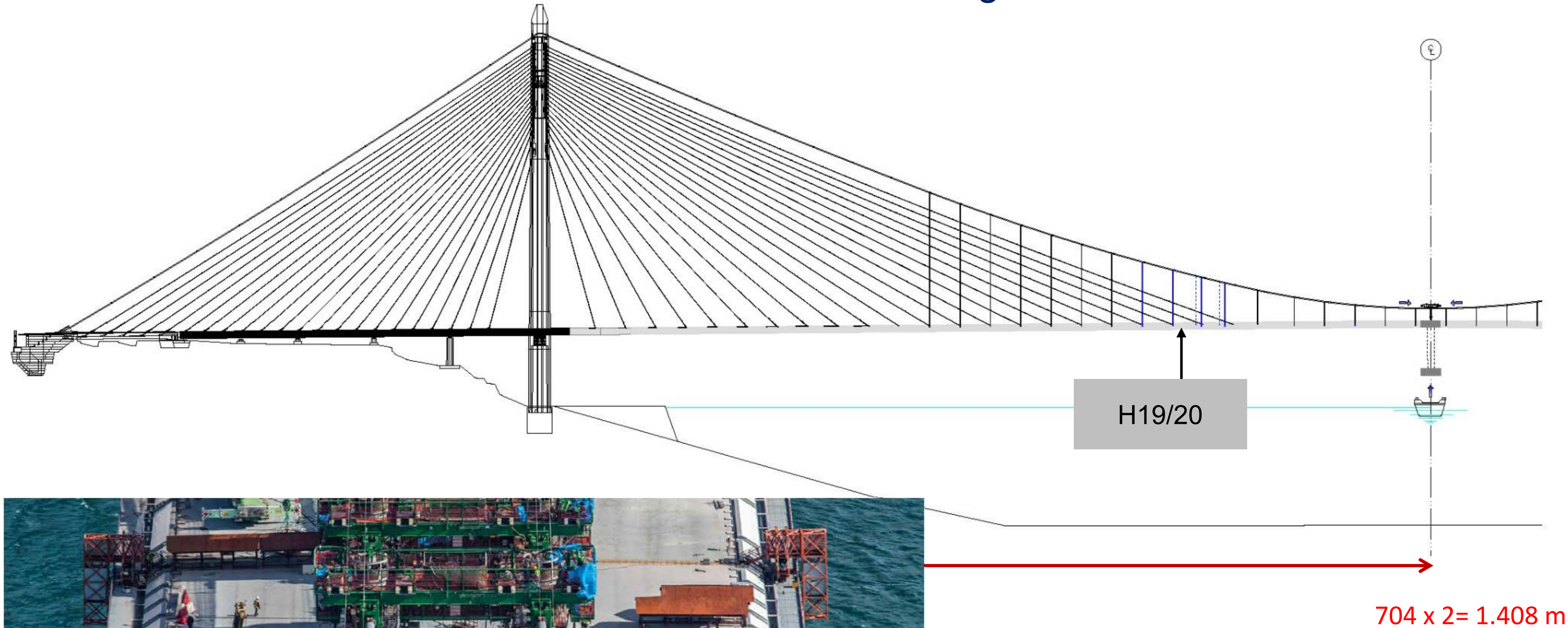
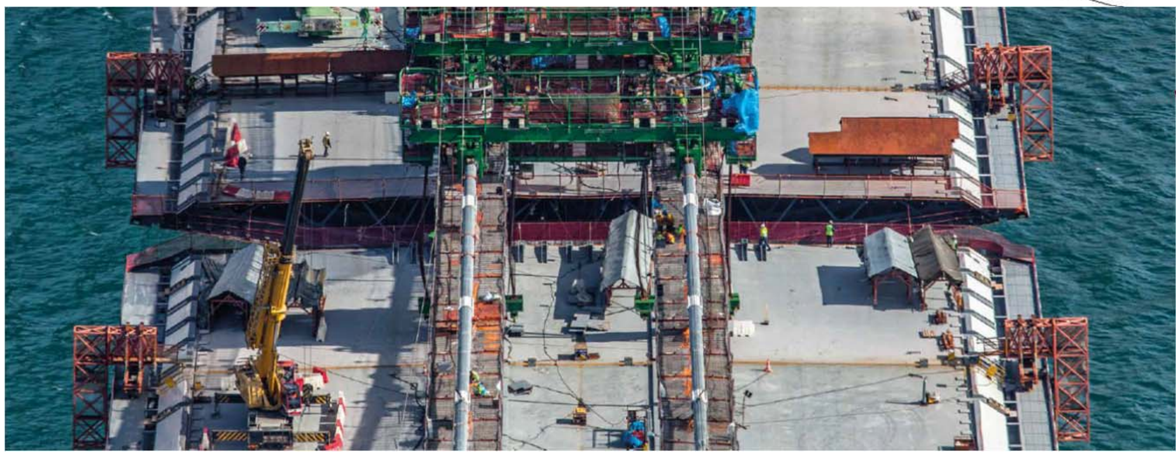
SUSPENDED PART
Key segment D99 – 8 m

- Shifting of the entire decks
- Erection key segment D99
- Welding between segments D99 and D28A
- Installation hangers H19A and H20A
- Shifting of the entire decks
- Welding between segments D99 and D28E
- Installation hangers H19E and H20E





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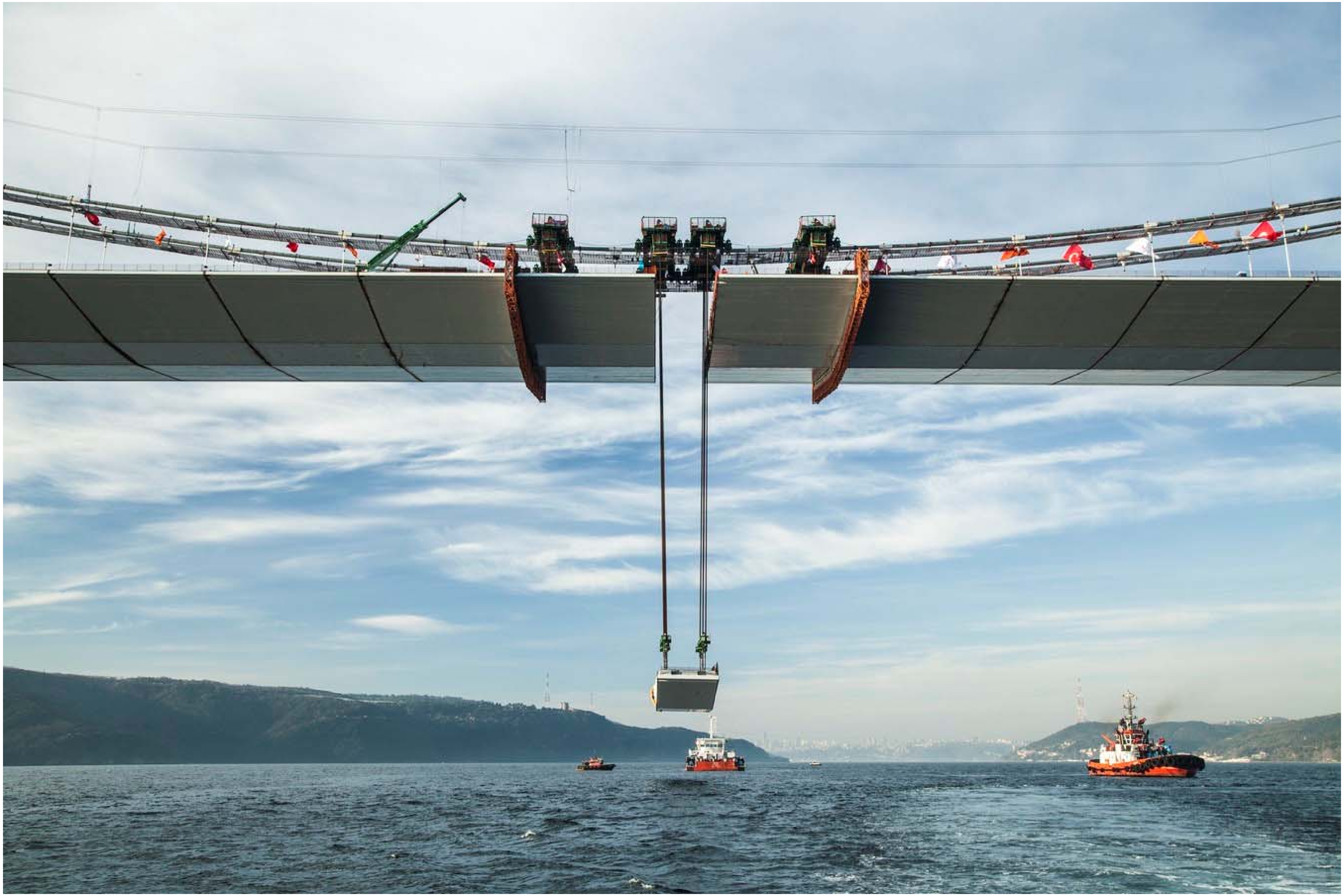
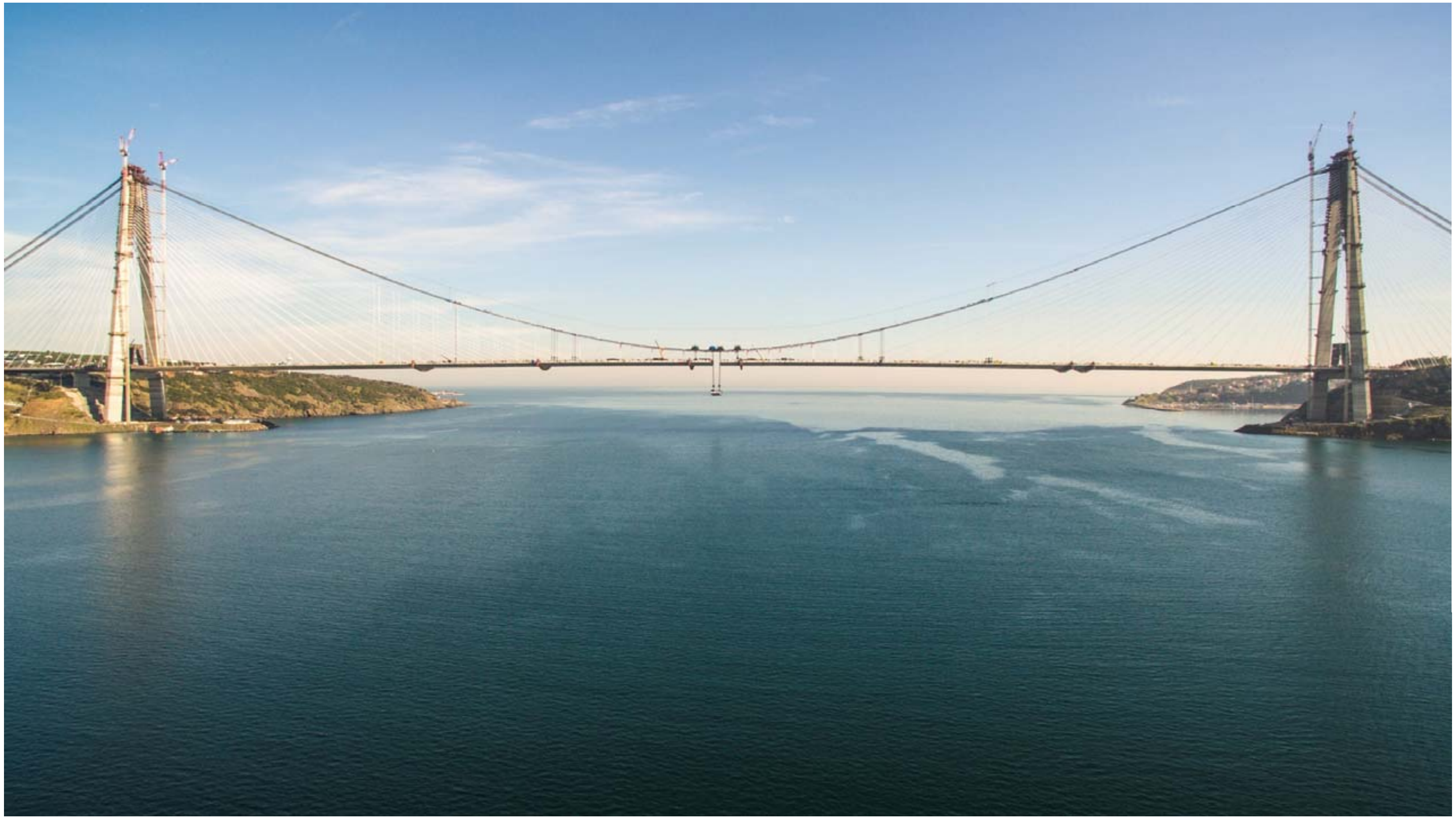


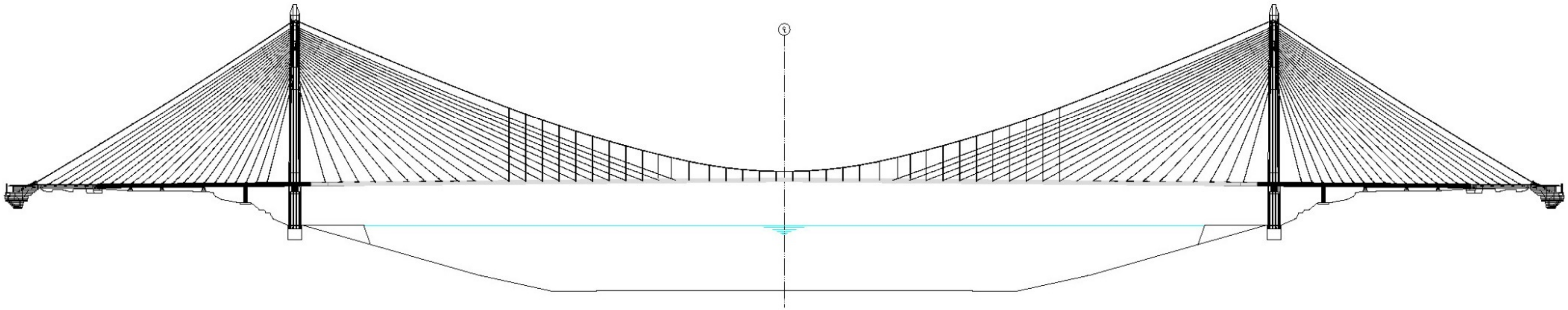


DECK COMPLETED

- Removal of the system of closure of the decks
- Installation of hangers H21 e H22
- Removal Temporary hangers TH21 and TH22

- Main Cable wrapping
- Removal of Lifting Gantry

- Second regulation of the stay cables



Length of the steel deck 2 x 680 m = 1.360 m
N.2 concrete span 2 x 24 m = 48 m
TOTALE 1.408 m

STEEL WORKS	CABLE			DECK	ANCHOR BOXES	TOP BEAM	**TOTAL**
	MAIN CABLE	STIFFENING CABLES	HANGERS				
	12,882 ton	8,816 ton	171 ton	45,500 ton	2,820 ton	920 ton	71,109 ton

REINFORCED CONCRETE WORKS	TOWER	CONCRETE DECK	GROUND APPROACH	ANCHORAGE BLOCK	**TOTAL**
CONCRETE AMOUNT	82,763 m^3	43,830 m^3	28,162 m^3	45,536 m^3	200,291 m^3
REINFORCEMENT AMOUNT	15,437 ton	7,150 ton	4,068 ton	5,924 ton	32,579 ton

EARTHWORKS	TOWER SHAFTS	INTERMEDIATE PIERS	GROUND APPROACH	ANCHORAGE BLOCK	**TOTAL**
	25,136 m^3	446,000 m^3	199,000 m^3	311,000 m^3	981,136 m^3

ASTALDI


O.
E.
Yavuz Sultan Selim
Köprüsü
Edirne
Beykoz
Çekmeköy
Ümraniye
500 m


Grazie per l'attenzione
POLITECNICO
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