MIDAS SQUARE

MIDAS SQUARE 공학 기술강연

1915 Çanakkale Bridge – Design & Construction

김정인 | DL E&C

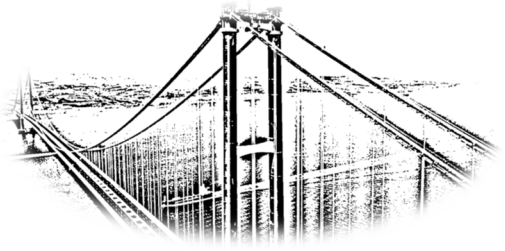
CONTENTS

Introduction

Project Background

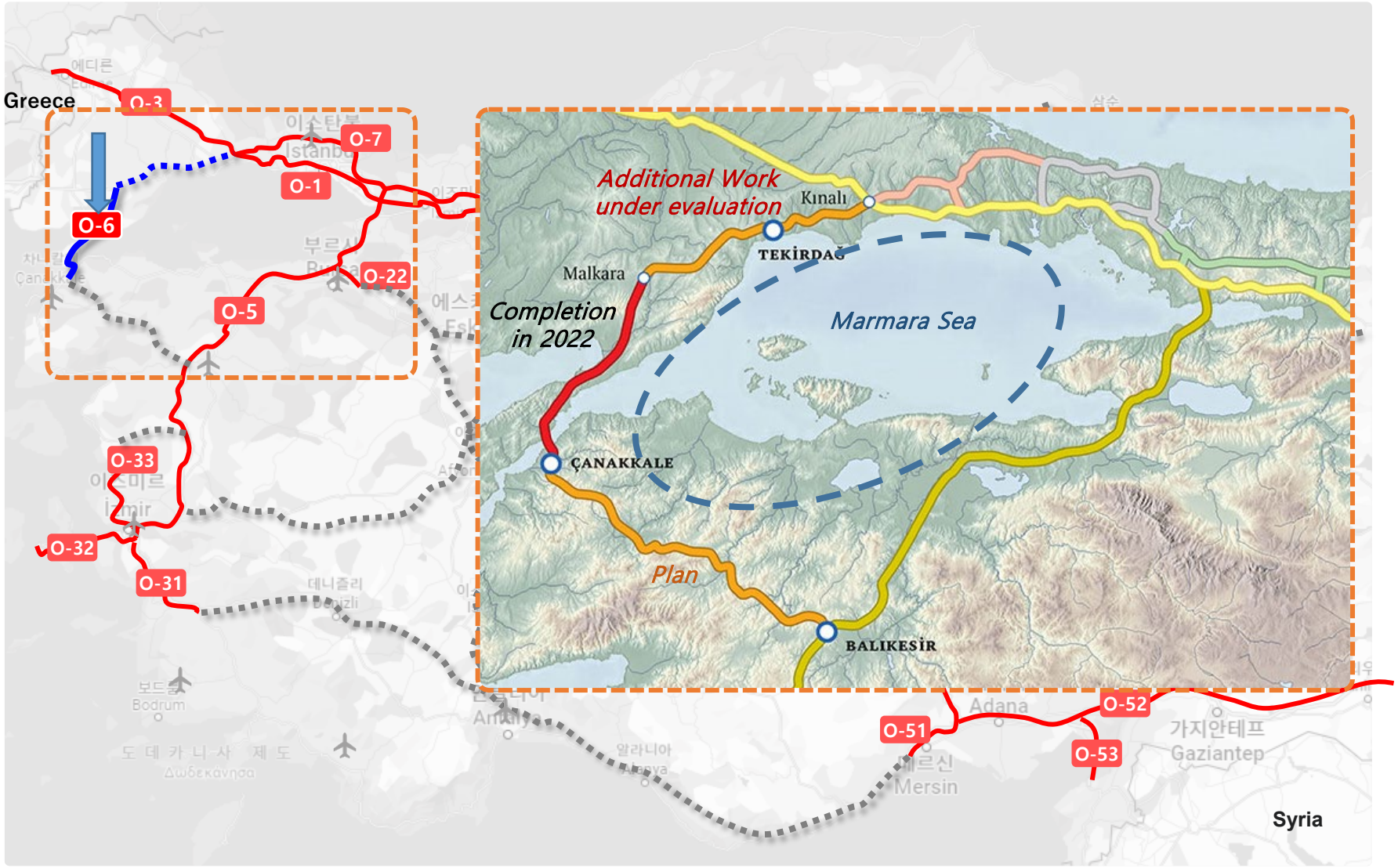
Highways in Türkiye

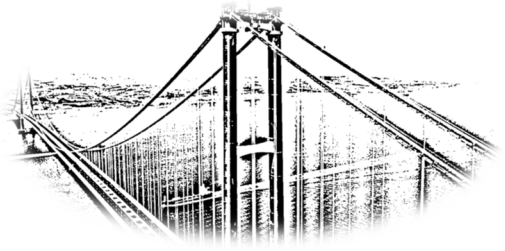
	Türkiye	Korea
Area	0.78mil km²	0.1mil km²
HW Length	4,000 km	4,800 km



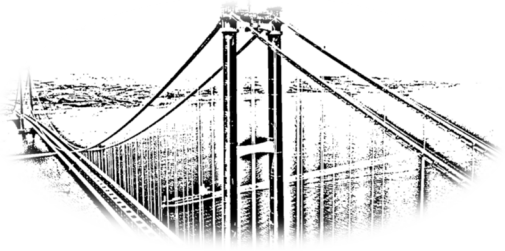
Project Background

Highways in Türkiye

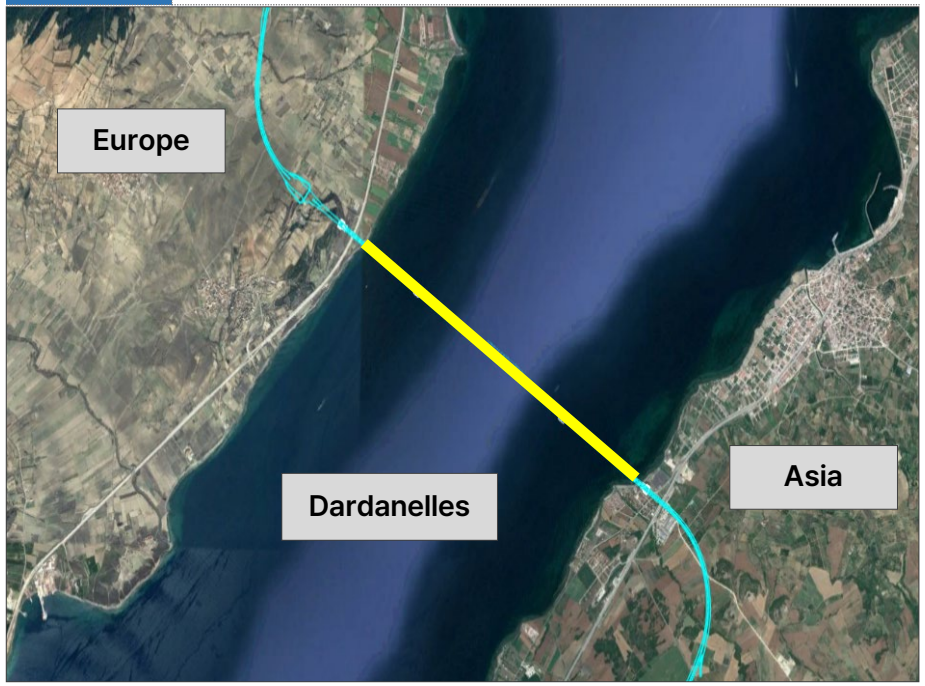




Project Information

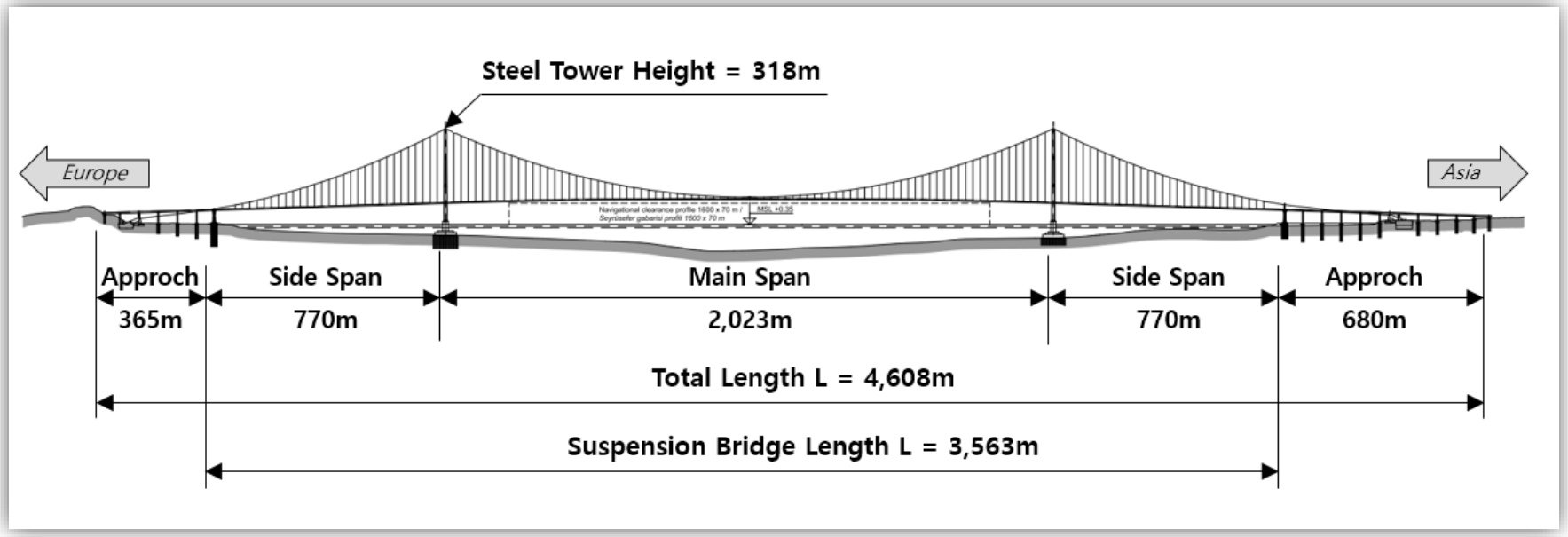


Title	1915 Çanakkale Bridge & Motorway PJT
Location	Malkara ~ Gelibolu ~ Çanakkale (Total 88.97km)
Cost	Appx. 3,139 mil. EUR (EPC : 2,430 mil EUR)
Type	BOT with MTG (Minimum Traffic Guarantee)
Equities	E&C, Limak, SK ecoplant, yapı merkezi
Period	Project Period(Const.+OP): 16years 2months Const. Period (56months, 2017.07~2022.03)



Project Information

1915 Çanakkale Bridge



Bridge Specification

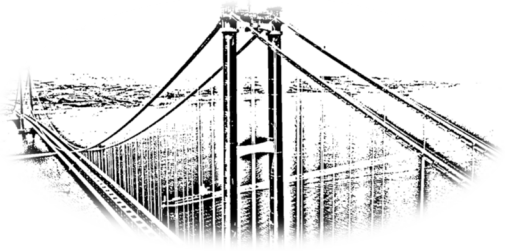
"World Longest Suspension Bridge"

Suspension Bridge	**3,563m** (770m + **2,023m** + 770m)
Approaching Viaduct	**1,045m** (680m + 365m)
Width of Deck	**45m** (6 Lanes → 2 x 3 Lanes)
Height of Tower	**318m** (H-shape Steel Tower)

Historical Significance

"The Pride of Türkiye People"

1915	Commemorating the victory at the Battle of Çanakkale in 1915
2023	Celebrating the 100th Anniversary(2023) of the establishment of the Republic of Türkiye (1923)

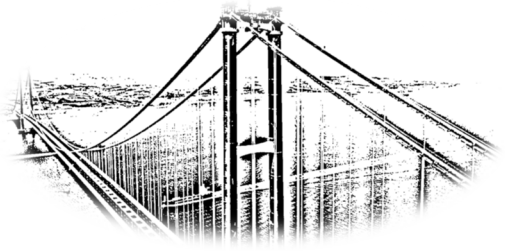


Project Information

Construction Schedule

Item	Duration (month)	2017	2018	2019	2020	2021	2022
Tower Foundation (Dry/Wet-Dock, Caisson)	24.4						
Tower (Erection & Saddle)	12.0						
Cable (Catwalk & Hauling System)	6.2						
Cable (PPWS & Compaction)	4.8						
Deck (Erection & Welding)	5.9						
Ancillary Work (Pavement , Barriers, etc)	2.6						

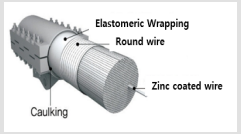
2017.07 ~ 2022.03 (56.1 Months)

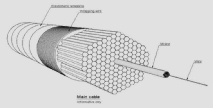


Project Information

Korea Contents

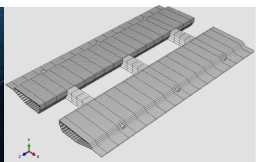
Cable wire & wrapping wire





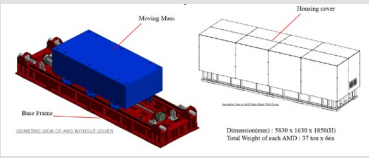
Company	KISWIRE
Quantity	Cable: 33,108 tons Wrapping: 542 tons

Steel Plate for Tower/Deck

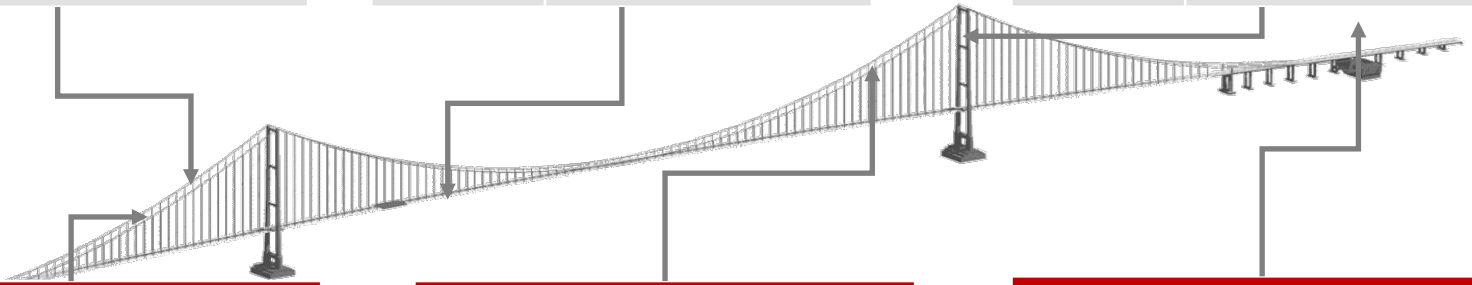



Company	POSCO
Quantity	**Tower: 36,310 tons** **Deck: 49,638 tons**

Active Mass Damper in Towers



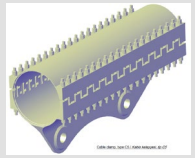
Company	TE Solution
Quantity	37ton x 6EA



Cable Erection & Engineering

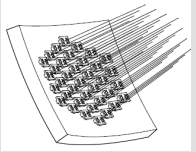
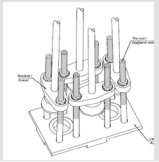

Company	KWANSOO ENVICO

Cable Clamp Manufacuring

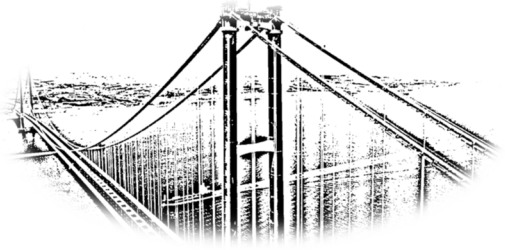


Company	SAMYOUNG M-TEK
Quantity	298 set

Anchorage Equipment

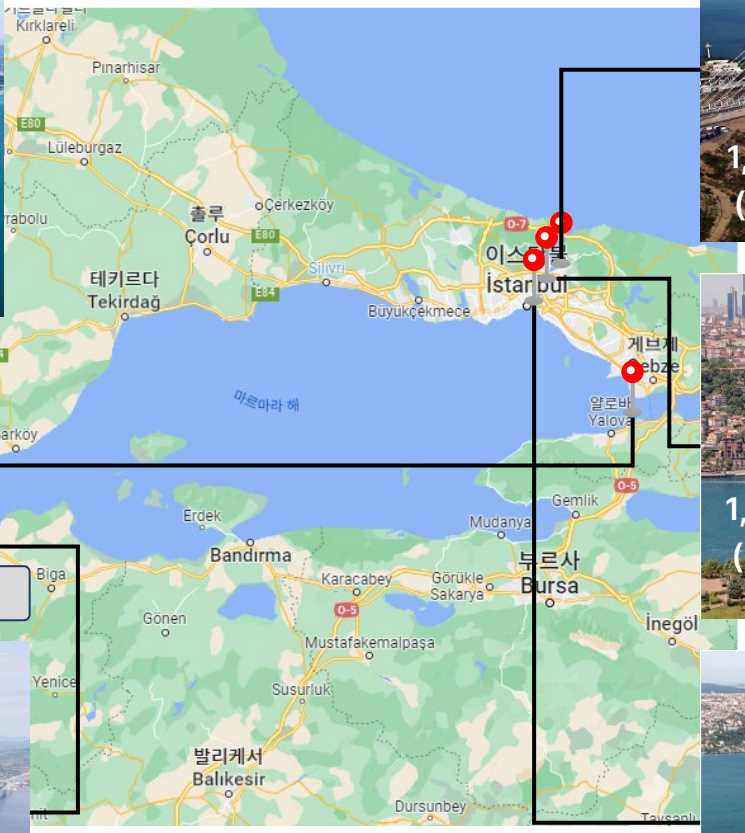
Company	SAMYOUNG M-TEK
Quantity	148 EA



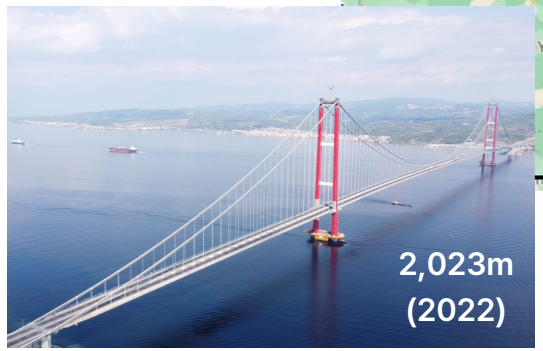
Project Information

Crossing straits

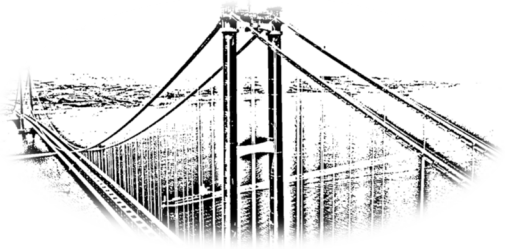
Osman Gazi bridge



1915 Canakkale bridge



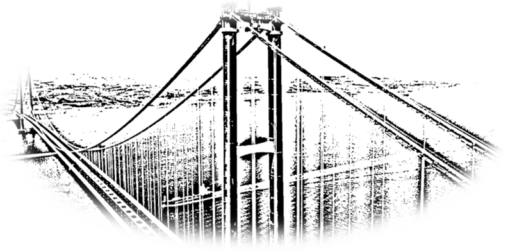
Bosporus Strait



Project Information

Suspension Bridges in the World

No.	Name	Location	Deck Width (no of Lanes)	Total Length (km)	Main Span Length (m)	Height of Tower (m)	Year of Completion
1	1915 Çanakkale Bridge		45(6)	4.6	2,023	318	2022
2	Akashi Kaikyo Bridge		35.5(6)	3.9	1,991	298	1998
3	Yangsigang Yangtze River Bridge		(6+4)	4.3	1,700	255	2019
4	Nansha Bridge(East)		49.7(8)		1,688	260	2019
5	Xihoumen Bridge		36(4)	2.6	1,650	211	2009
6	Great Belt Bridge		31(4)	2.7	1,624	254	1998
7	Osman Gazi Bridge		30.1(6)	2.7	1,550	236	2016
8	Yi Sun-Shin Bridge		25.7(4)	2.3	1,545	270	2013
9	Runyang Bridge		39(6)	2.4	1,490	215	2005
10	2nd Dongtinghu Bridge		35.4(4)	2.4	1,480	206	2018

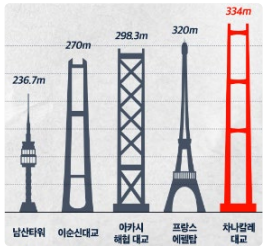


Design

Design Summary

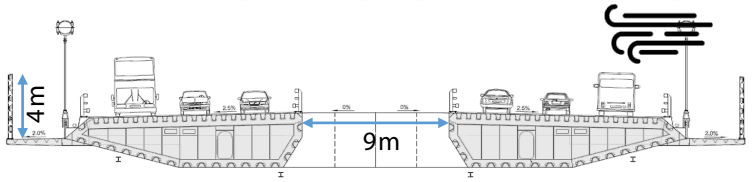
Main Design Features

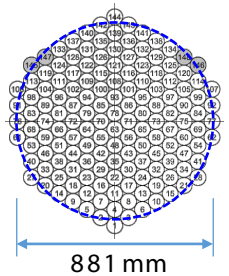
334 M
the highest steel tower



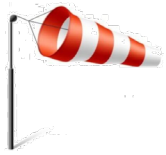
streamlined twin box deck 45 M x 3.5 M

flutter over 91 M/S



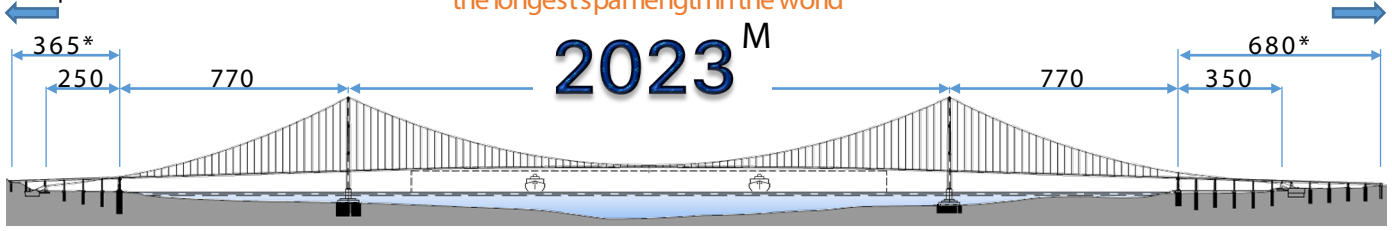


1960 MPa
the highest tensile strength



29.0 M/s
10m. ground level
10min. wind speed
100yrs. return period

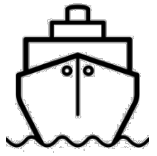
Europe — the longest span length in the world — Asia



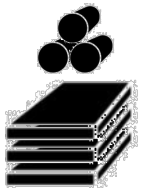
* Approach bridge

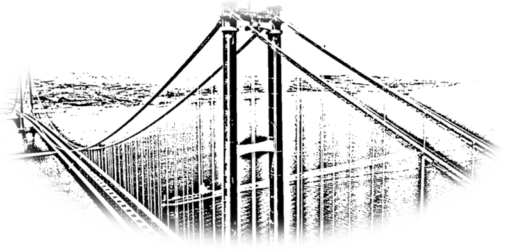
8 Magnitude
Earthquake return period 2475yrs.

1600 M x 70 M
Navigation Channel



120,000 Ton
Korean contents wire and steel plates





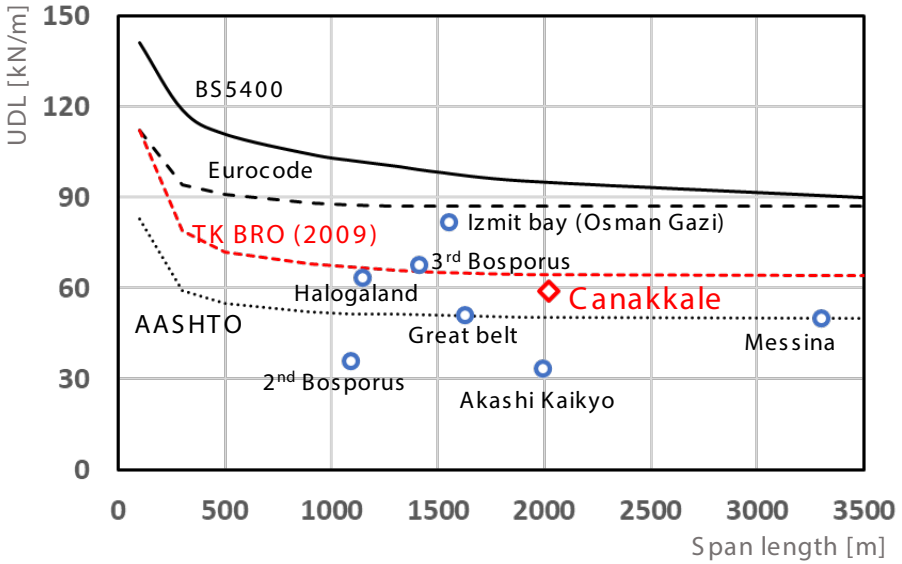
Design

Design Loads

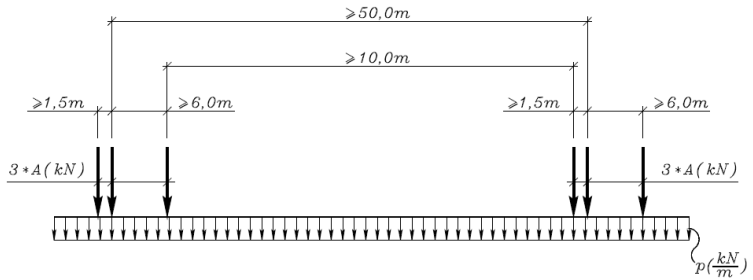
Design Loads

Live Loads

Uniform Distributed Load



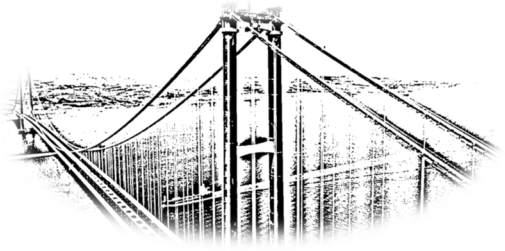
TK BRO ; Trafikverkets tekniska krav Bro
+ up to 200m : equivalent to Eurocode
+ over 200m : reduction



Figur B.3-2 Trafiklast för spännvidder över 200 m

Standard	Loaded length	UDL [kN/m]	Load factor	Design UDL [kN/m]
EN1991-2	L ≤ 200 m	81.8	1.35	110.4
KGM-45	L > 40 m	39.0	1.75	68.3
TK BRO	L > 200 m	58.8	1.35	79.4

Location	Load Groups Axle Loads, Q_{ik} (kN)	UDL System q_{ik} or q_{rk} (kN/m²)
Notional Lane 1	250	4.0
Notional Lane 2	170	3.0
Notional Lane 3	0	2.0
Other Notional Lanes	0	2.0
Remaining Areas	0	2.0



Design Loads

Wind Loads

Wind data survey (2012-2017)

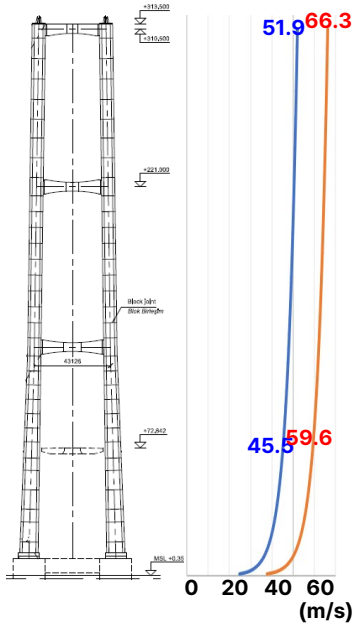
V_b=26.0m/s

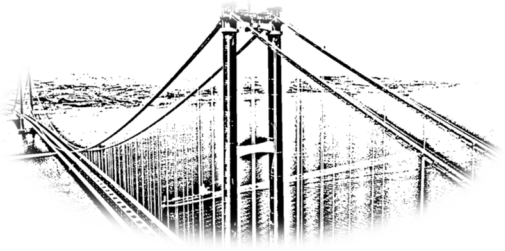
⇩

+ 10%
uncertainty

⇩

V_b=29.0m/s

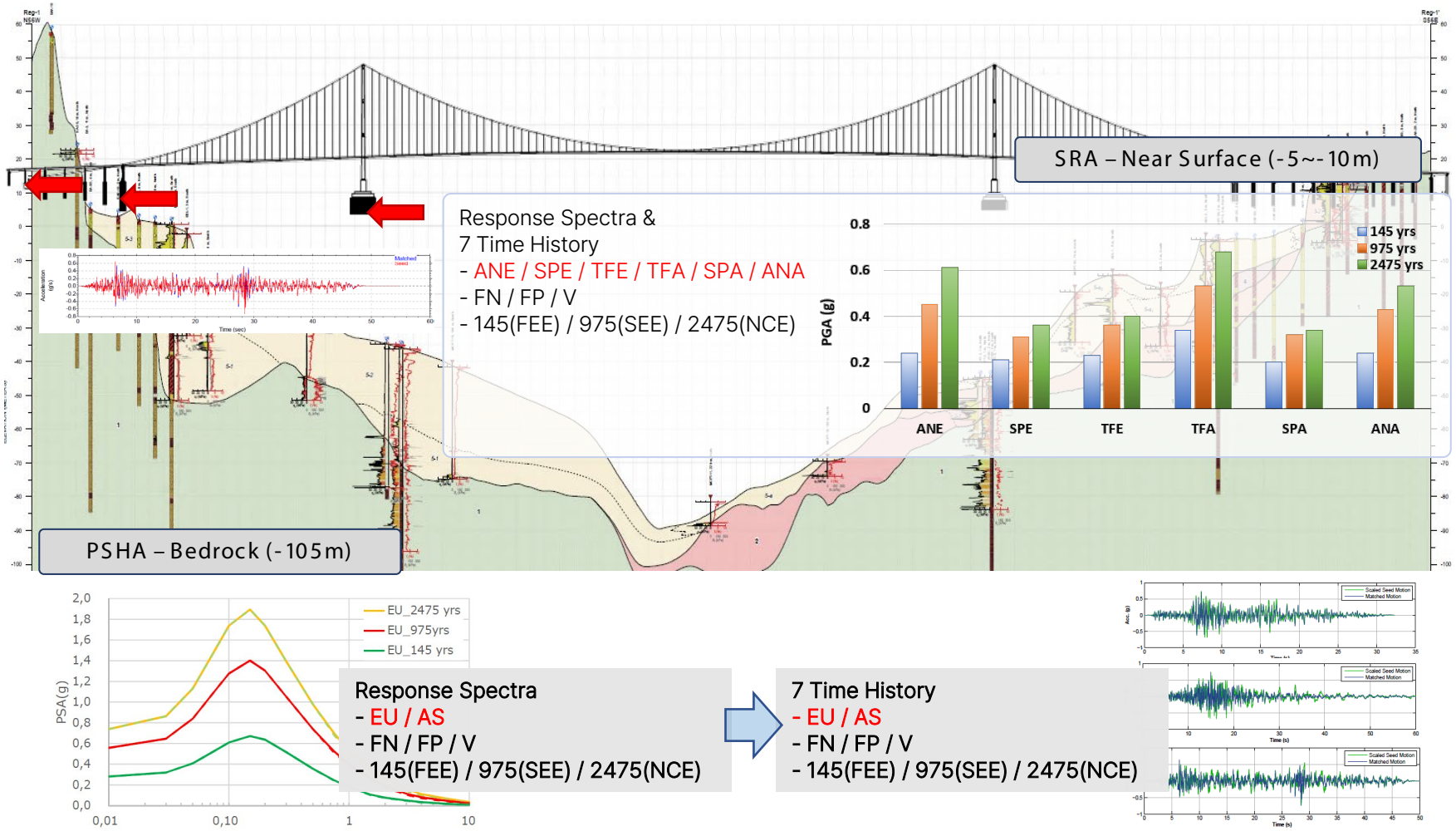


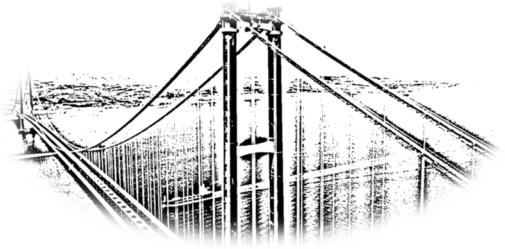


Design Loads

Seismic Effects

Seismic THA

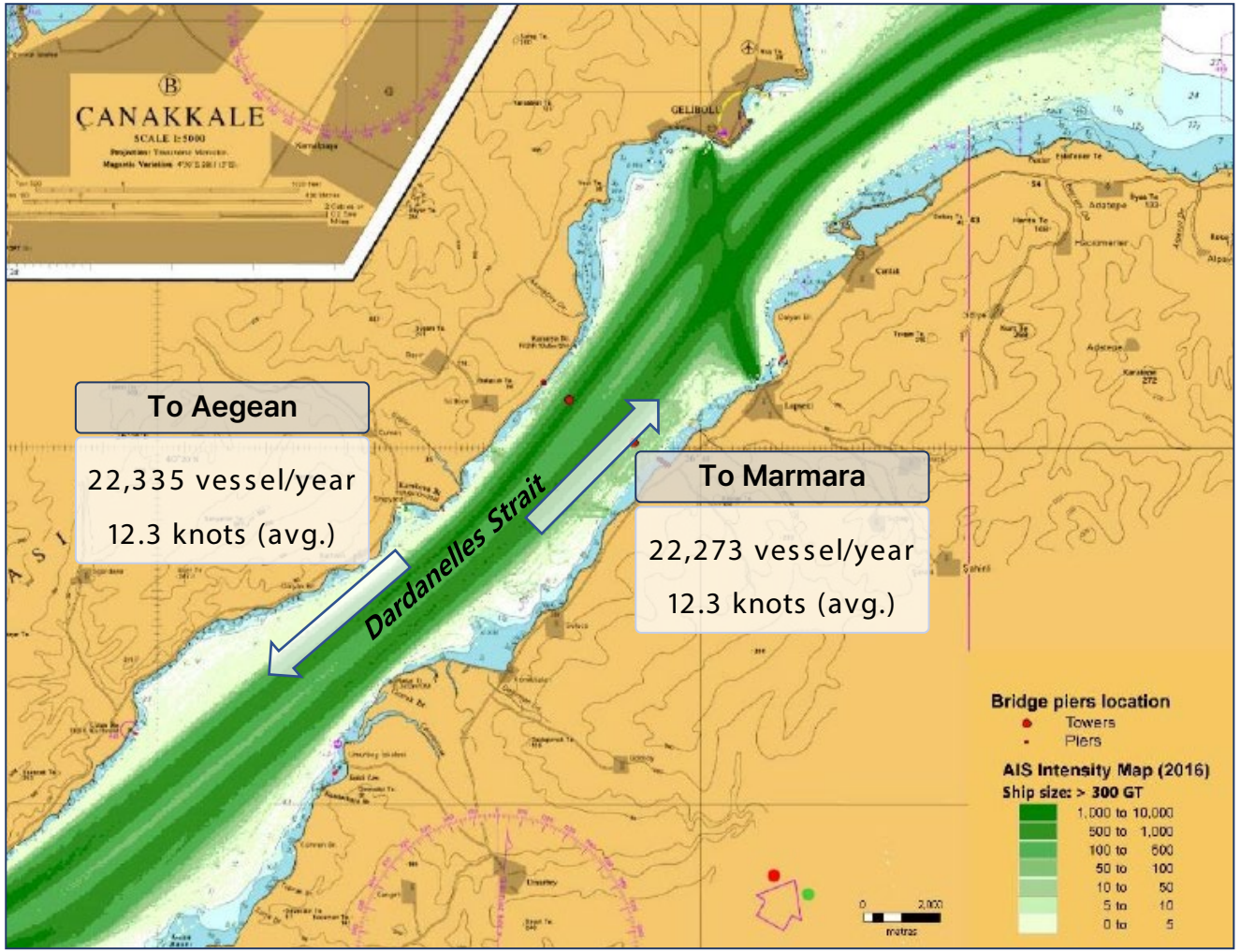


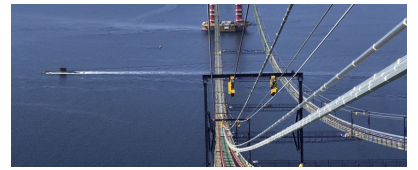


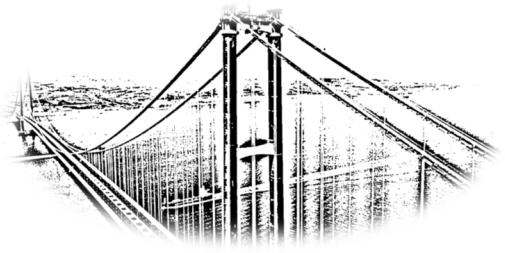
Design Loads

Ship Collision Impact

Heavy Traffic







Design Loads

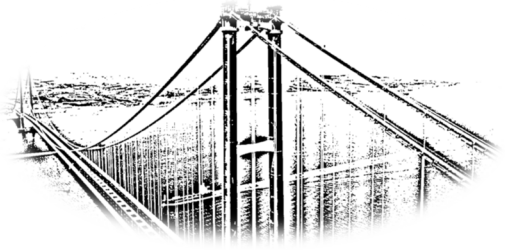
Ship Collision Impact

Collision Force

Ship collision risk acceptance criteria

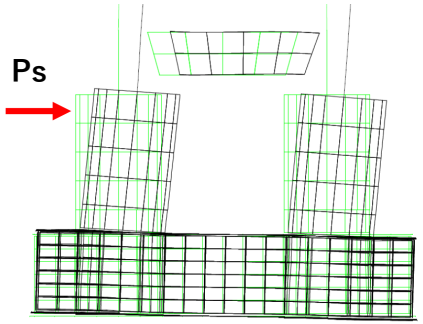
= 10^{-4} / year

Standard	Container	Bulk Carrier
DWT [Ton]	180,000	260,000
Avg. Speed [knots]	14.3	11.9
Ps [MN]	370	

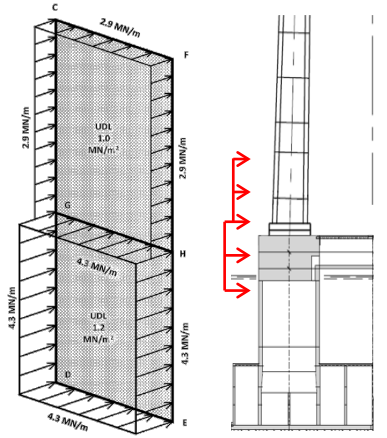


Example of container. 200,000DWT
400m X 59m X 33m, Draft 16m

Example of bulk carrier. 210,000DWT
300m X 50m X 25m, Draft 18m



Global safety



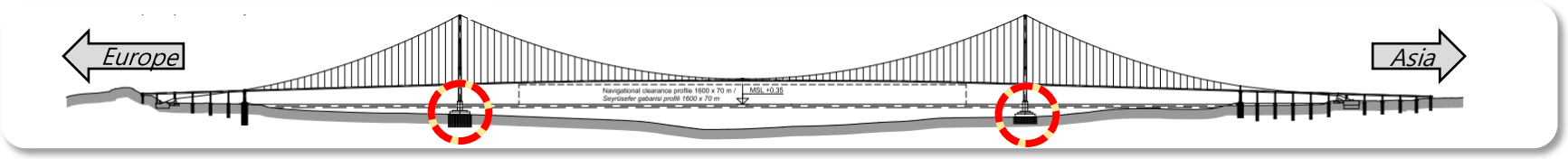
Local safety

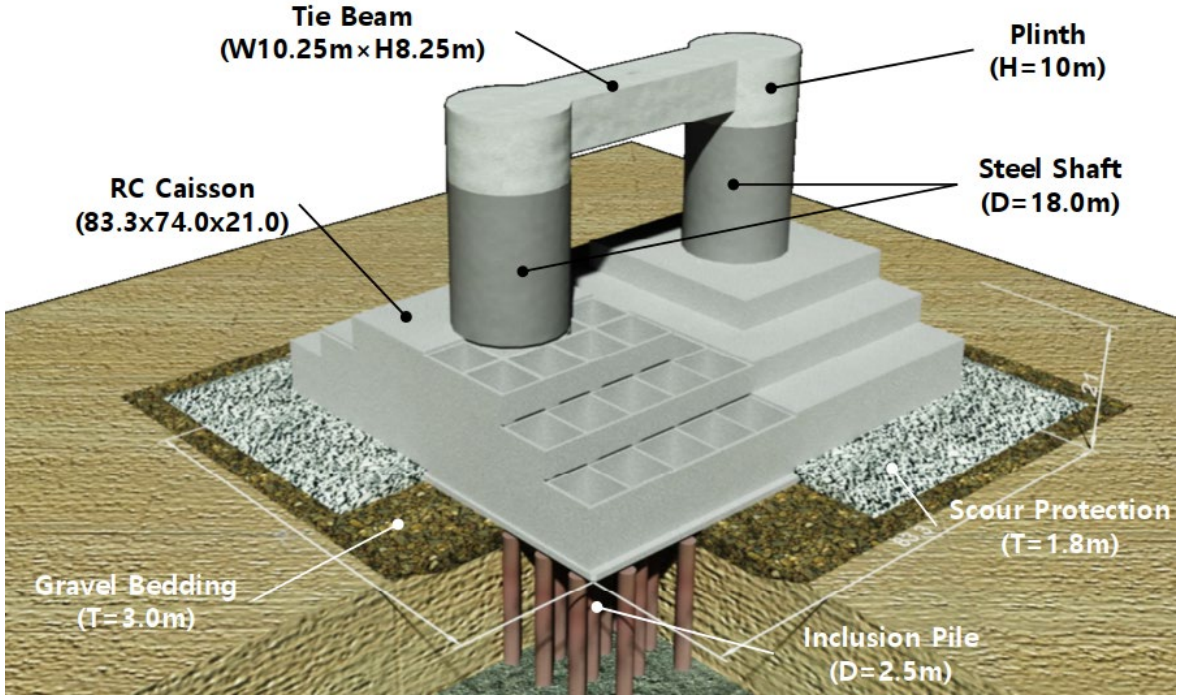
Design

Sub-Structures

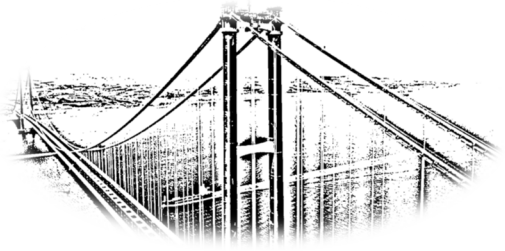
Tower Foundation Design

Tower Foundation Layout





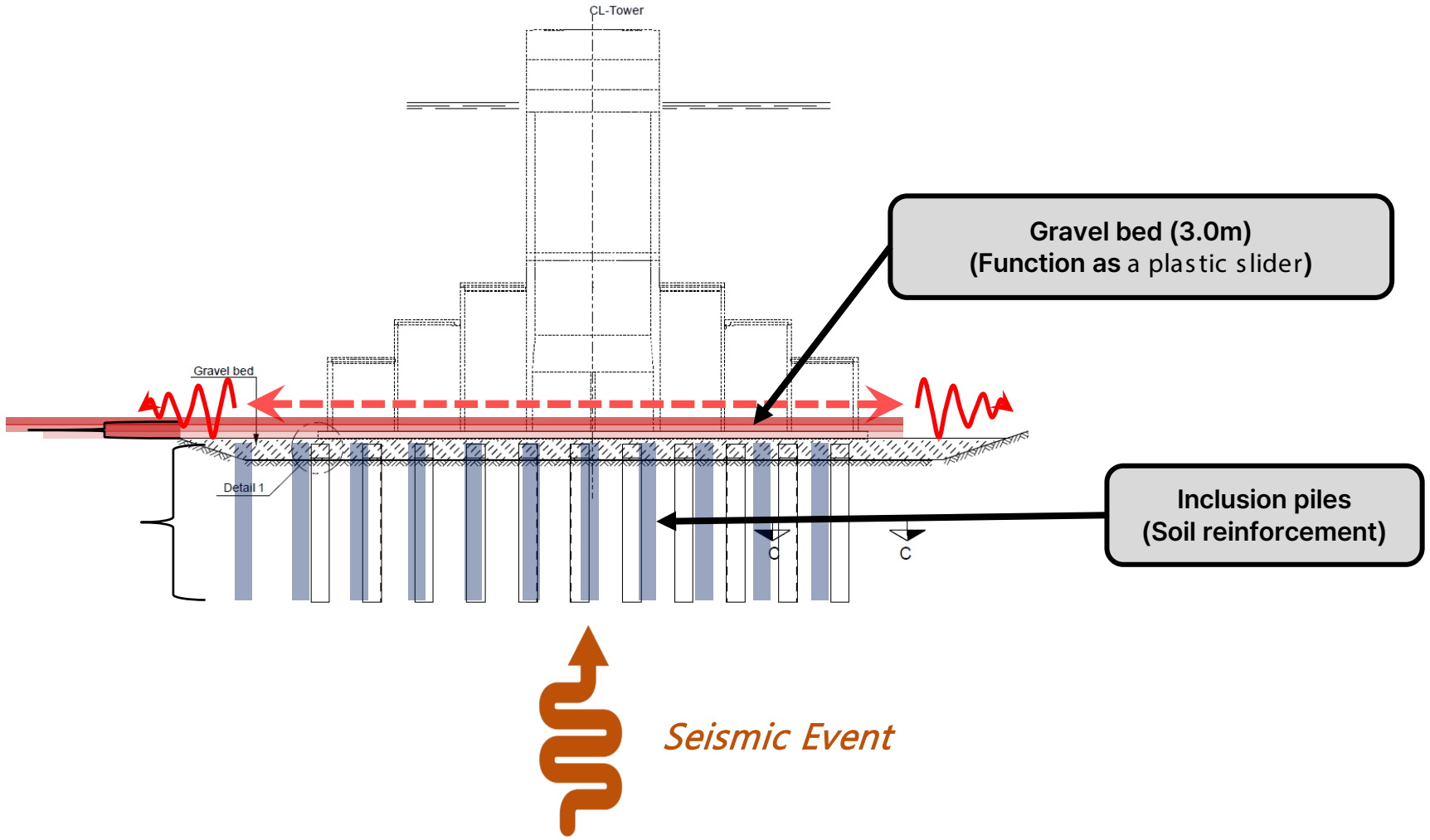
Item	Quantity
Concrete	64,421 m³
Reinforcement	19,962 Ton
Gravel Bed	86,765 m³
STEEL PILE	165(A) + 203(E) =368 ea

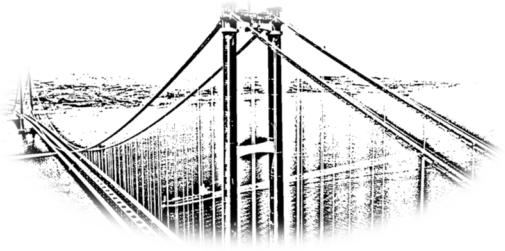


Tower Foundation Design

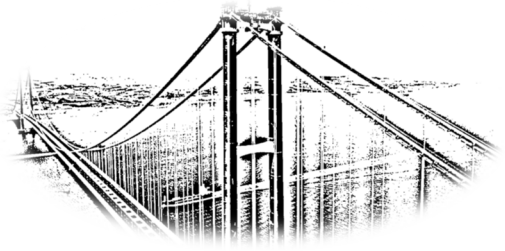
Tower Foundation Layout

Seismic Design Concept

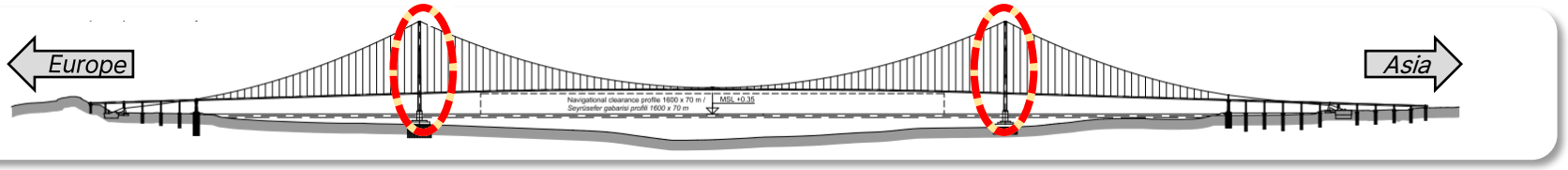


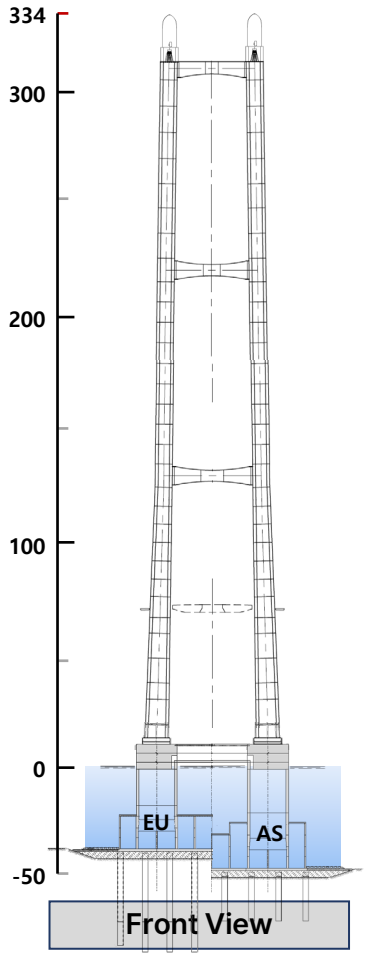


Tower Design

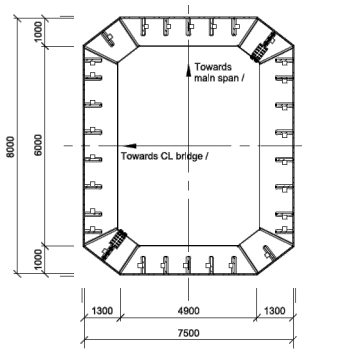


Tower Leg Design

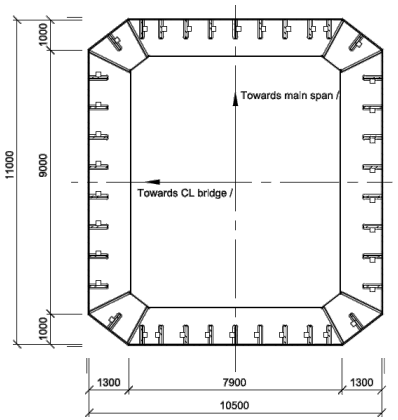




Front View



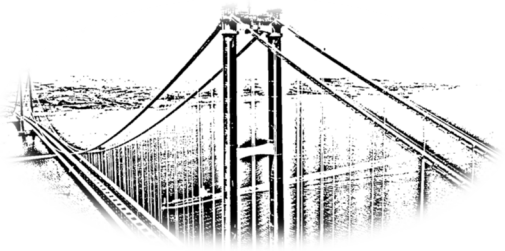
Upper Section



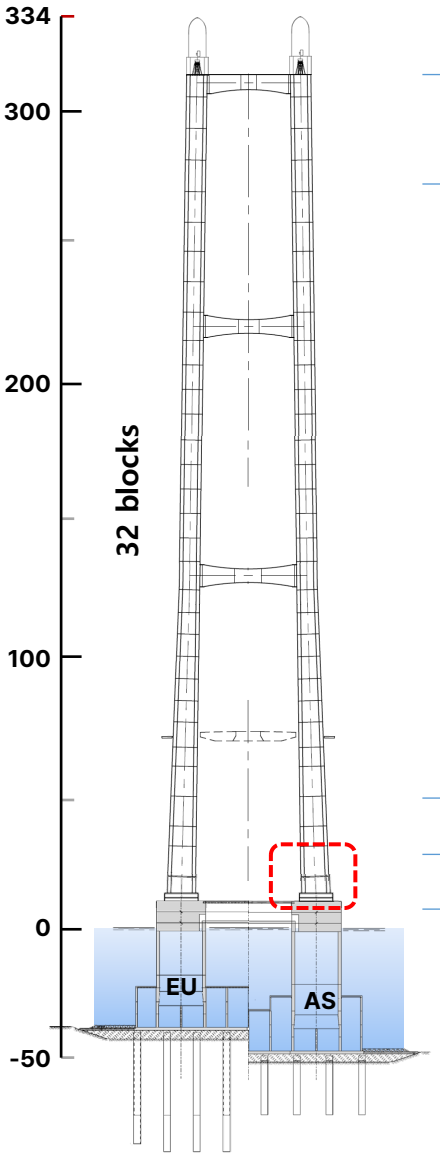
Lower Section

Lower Section	11.0 m x 10.5 m
Upper Section	8.0 m x 7.5 m
Saddle IP Elevation	318 m
No. of block	32 ea (per 1 leg)
Steel Quantity	2 x 18,120 ton = 36,240 Ton
Block height	7,040 m ~ 11,67 m
Steel Grade	S460, S620

Tower Design

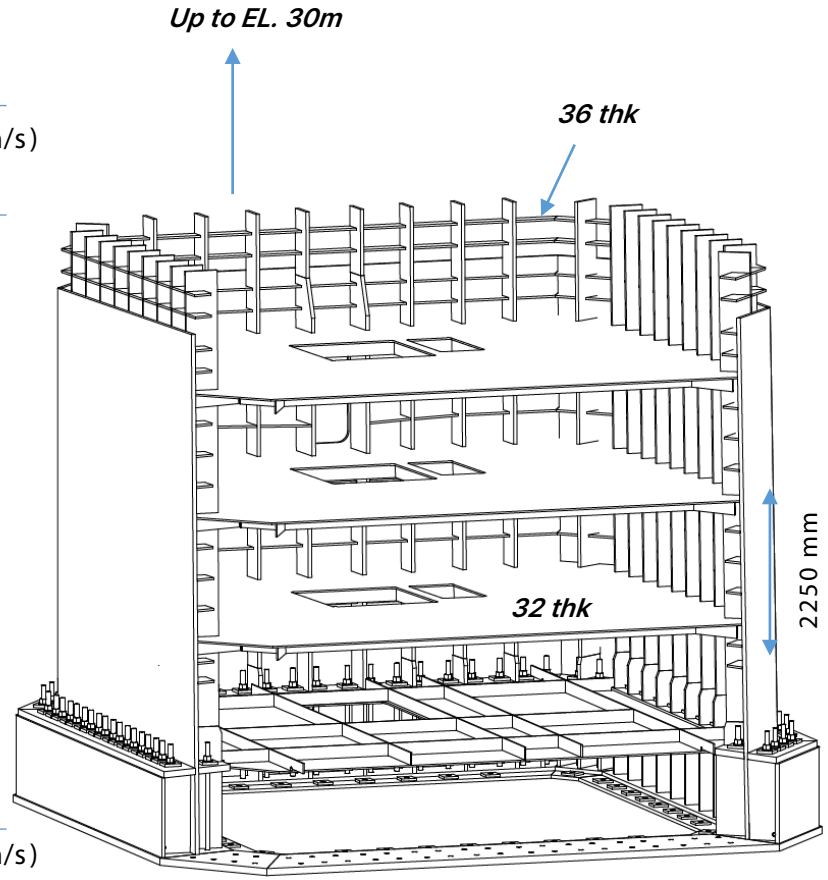


Tower Leg Design



[Governing Load]

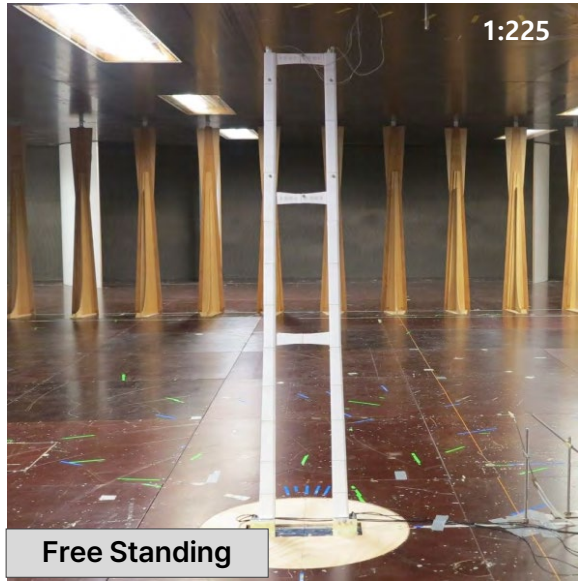
- Wind load ($V_{b,0}$ = 29.0m/s)
- Traffic + Wind load ($V_{b,0}$* = 14.7m/s)
- Wind load ($V_{b,0}$ = 29.0m/s)
- Ship impact load



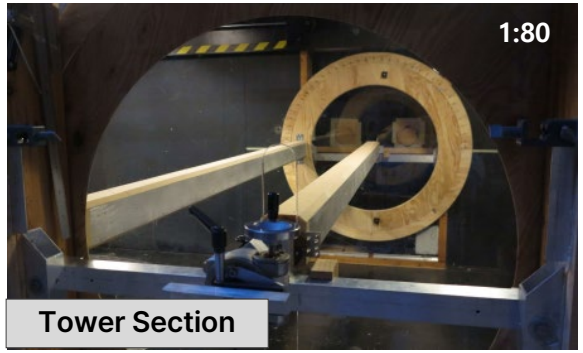
Tower Design

Aerodynamic Design of Tower

Wind Tunnel Test for Tower

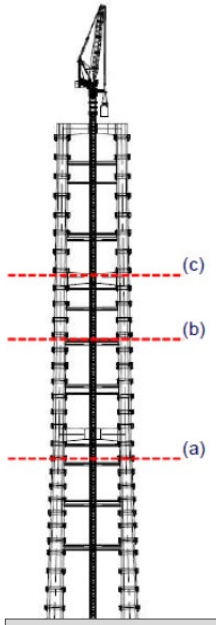


Free Standing



Tower Section

AMD Application

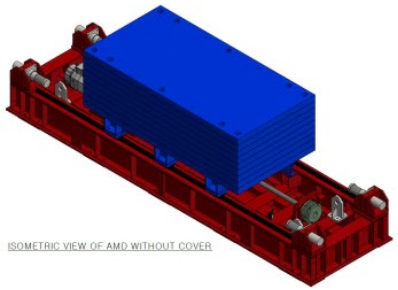


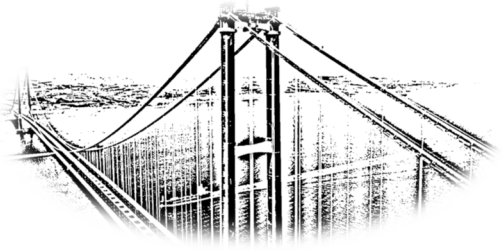
AMD Location


Permanent installation
(c) 3rd location of 2 sets of AMD
(Leg block 24, EL+225m, stage 37)


(b) 2nd location of 1 sets of AMD
(TCB No.5, EL+179.843m, stage 34)


(a) 1st location of 2 sets of AMD
(TCB No.3, EL+107.853m, stage 19)

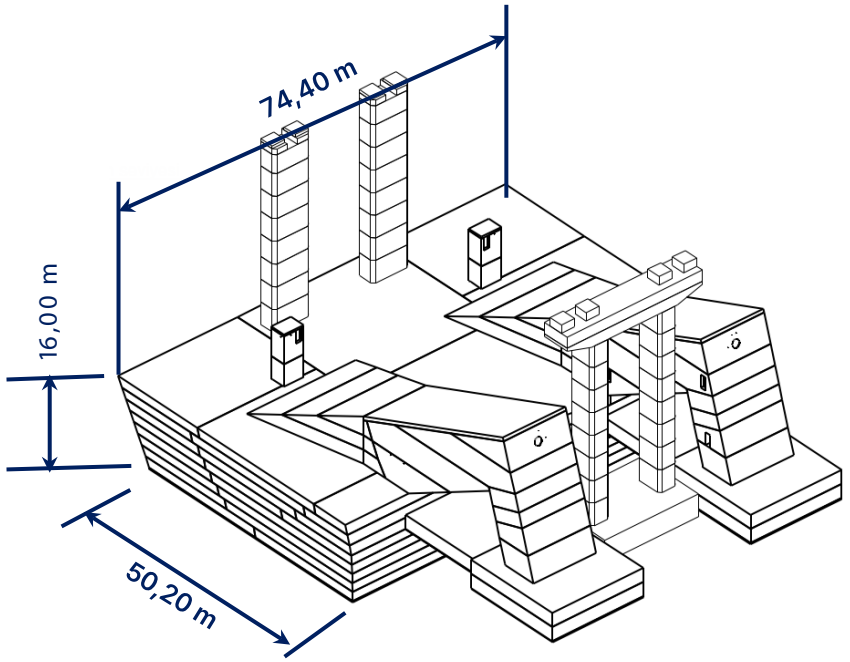




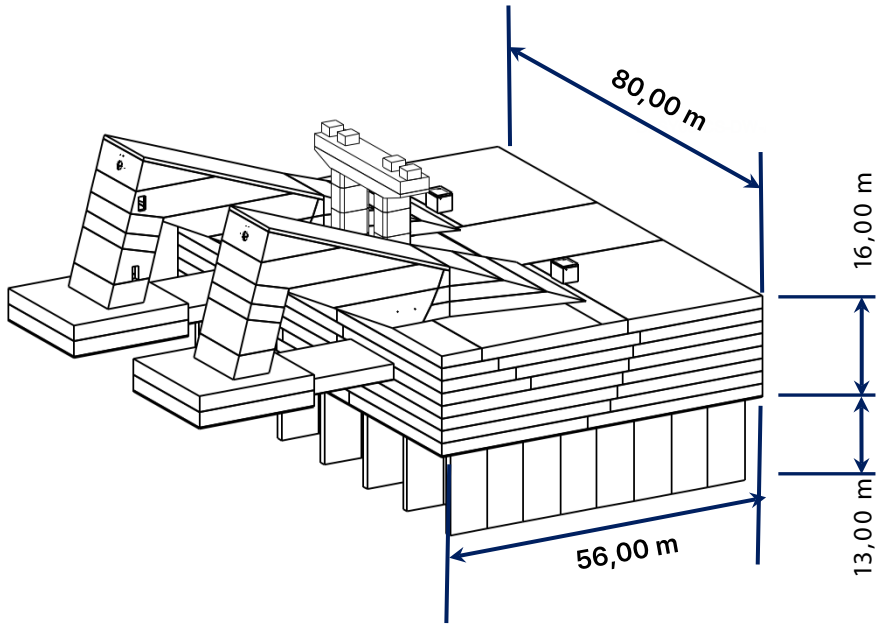
Anchor Block Design

Anchor Block Layout

Europe Anchor Block

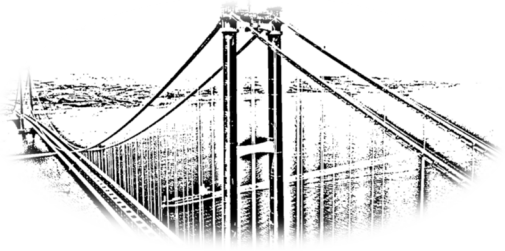


Asia Anchor Block



Item	Quantity
Excavation	165,640 m³
Concrete	68,845 m³
Rebar	6,340 Ton

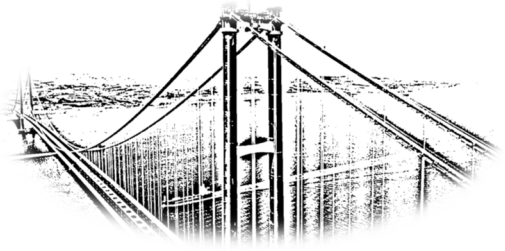
Item	Quantity
Excavation	150,227 m³
Concrete	92,191 m³
Rebar	10,606 Ton



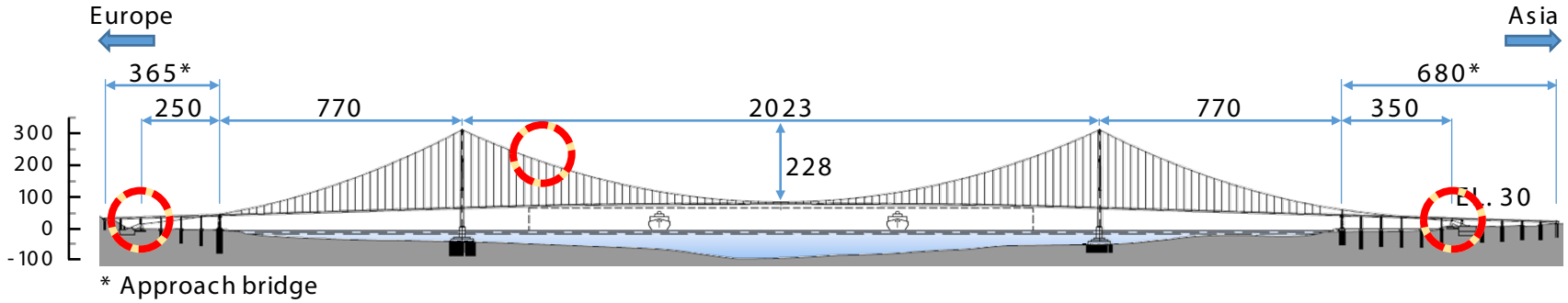
Design

Super-Structures

Cable Design



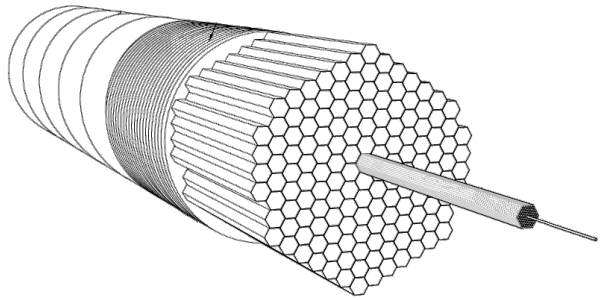
Cable Systems



* Approach bridge

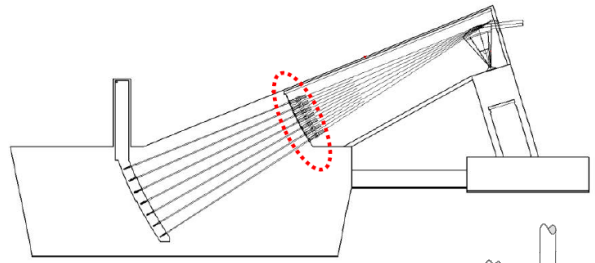
Main Cable

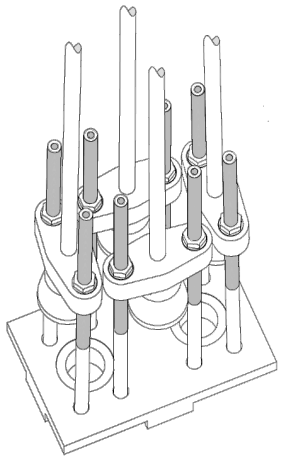
PWS 127 - Φ5.75mm (1960 MPa)
Main ; 144 EA (0.475 m², 869 mm)
Side ; 148 EA (0.488 m², 881 mm)



+ galvanizing 300g/m²(99.99% Z2)
+ wire wrapping Φ3.5mm (1 layer)
+ Elastomeric wrap (2 layer)
+ Dehumidification system

Anchoring System

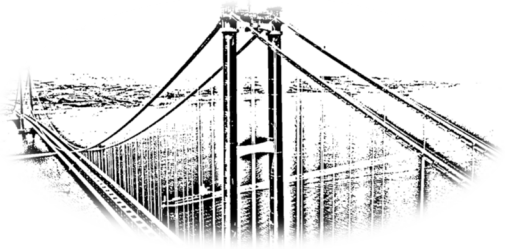




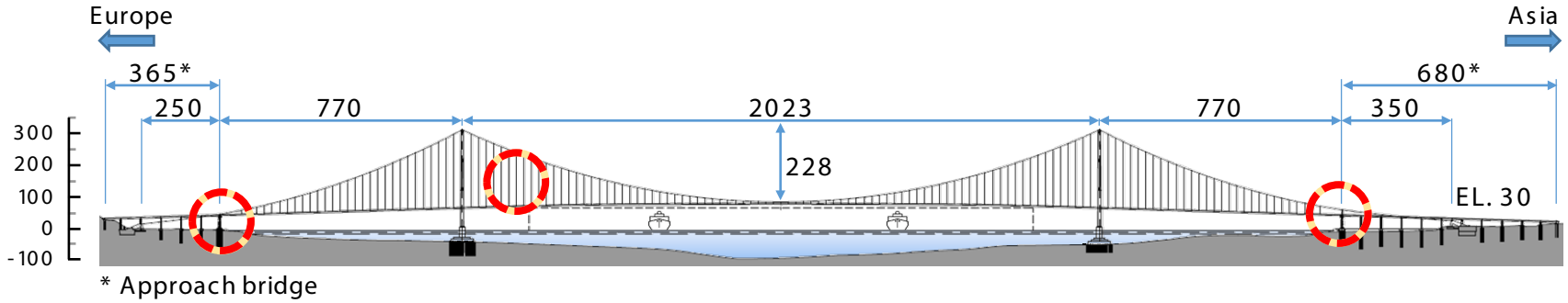
Per strand ;
2- M64 (Class 10.9)

Per 4 strands ;
2 X 31-Φ15.7mm (1860 MPa)

Cable Design

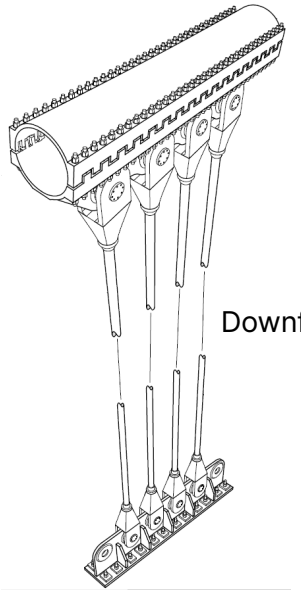


Cable Systems



* Approach bridge

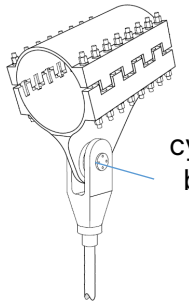
Tie-Down System



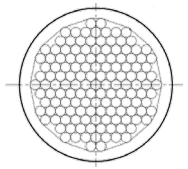
PWS 367 – Φ7mm
(1770 MPa)

Downforce = 12 MN

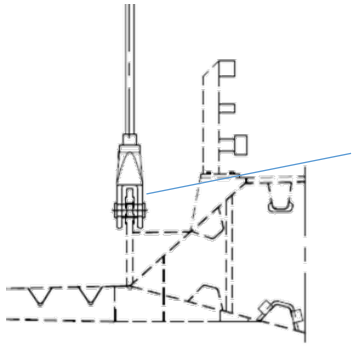
Hangers



cylindrical bushing



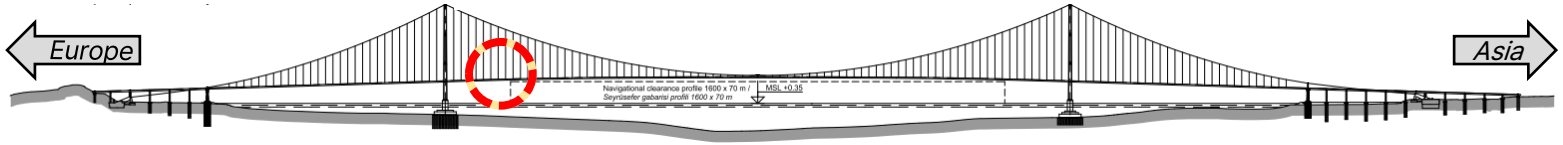
PWS 139/151 – Φ7mm
(1770 MPa)

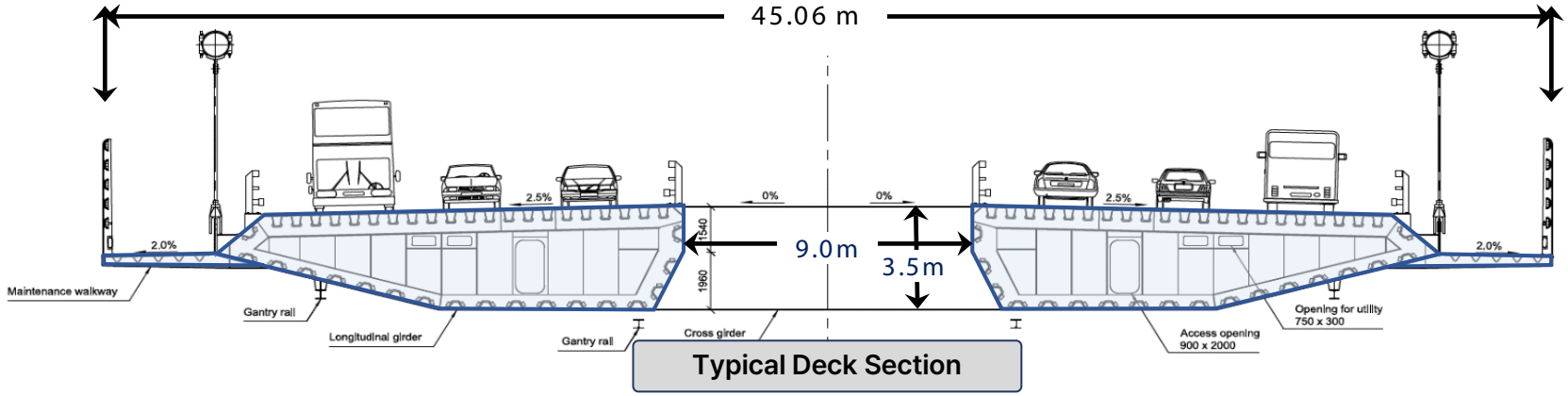


Spherical bearing

Deck Design

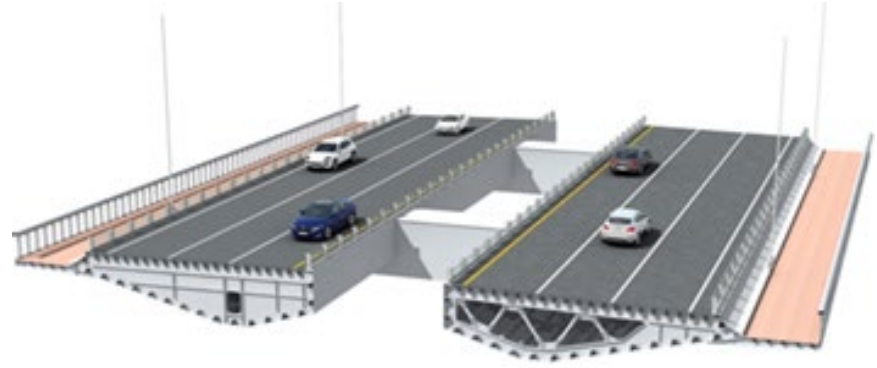
Deck Structures

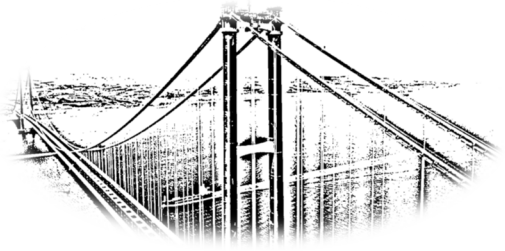




Typical Deck Section

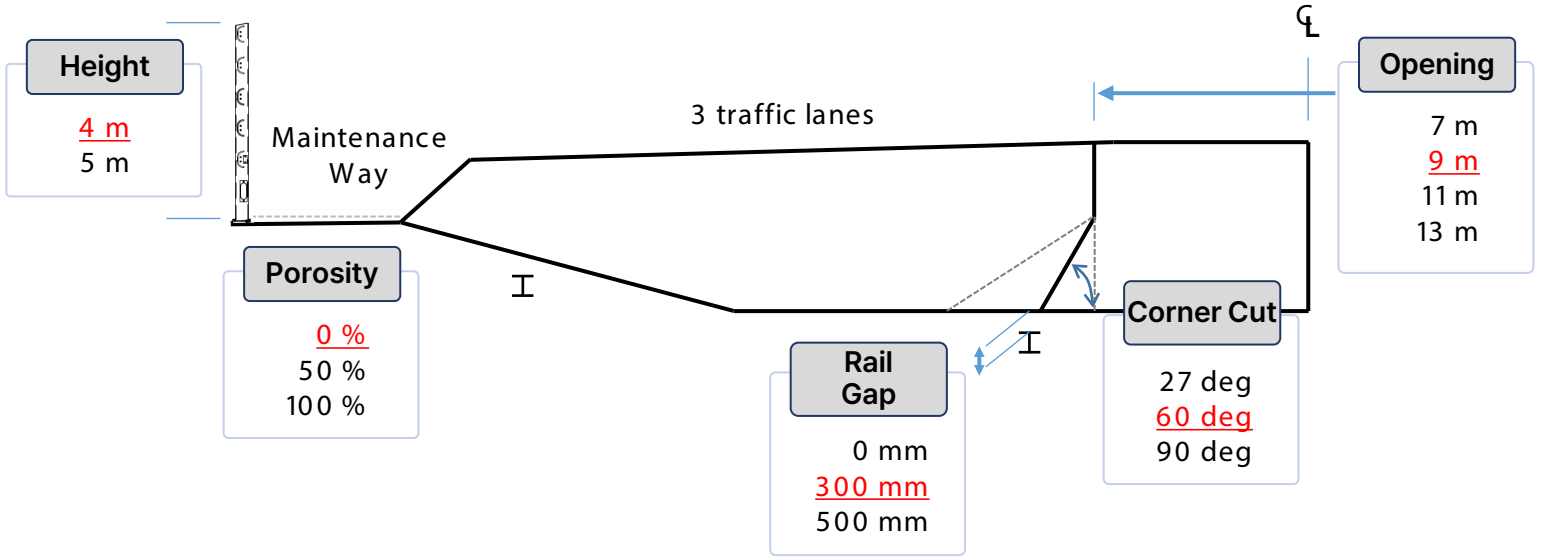
Type	Twin Box Steel Deck System
Block	89 Nos (Max. 8000 kN/ block)
Quantity	54,000 Ton
Steel Grade	S355 / S460



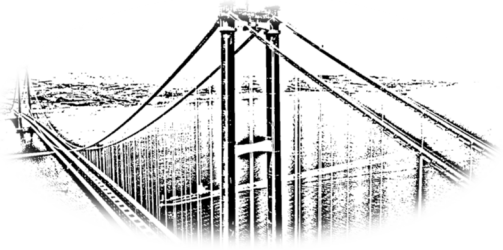


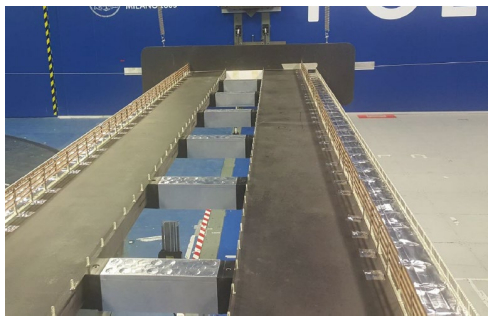
Deck Design

Aerodynamic Design of Deck



Weight : 14 ton/m
No galloping
Flutter > 91m/s

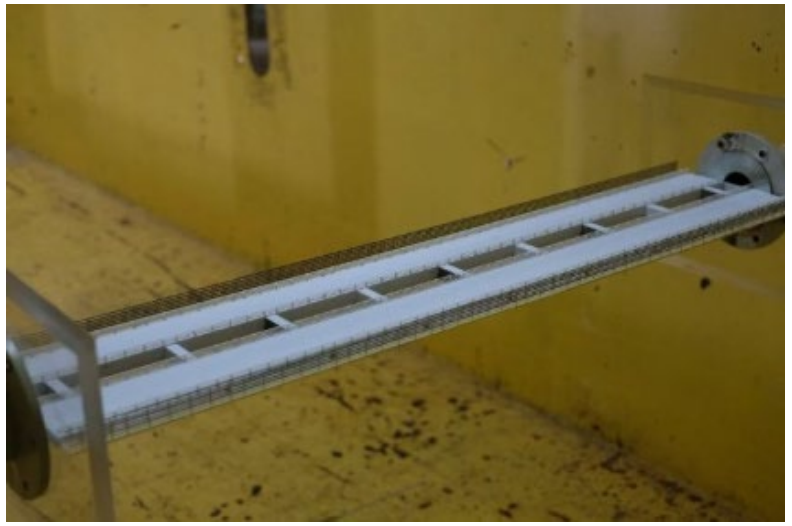




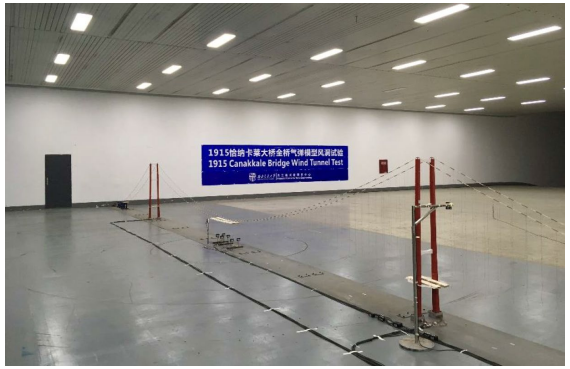
Deck Design

Aerodynamic Design of Deck

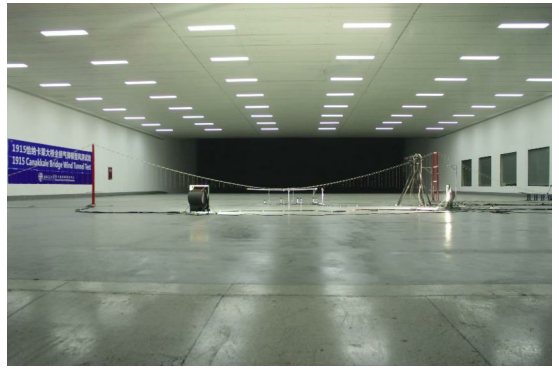
Full Bridge Model (In-service)



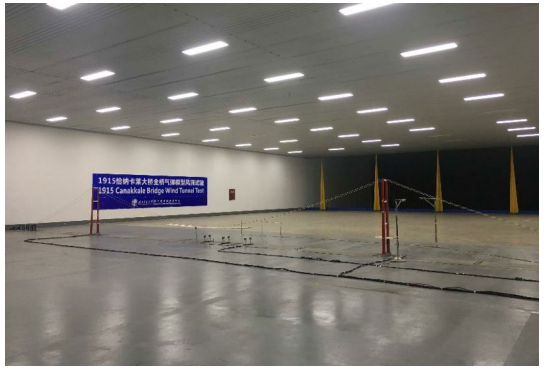
Section Model (In-service)



10% Deck Erection

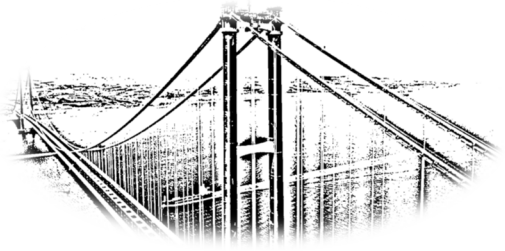


20% Deck Erection



30% Deck Erection

Erection Stage Models

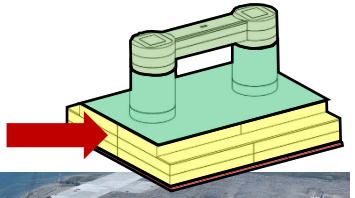


Construction

Tower Foundation

Tower Foundation

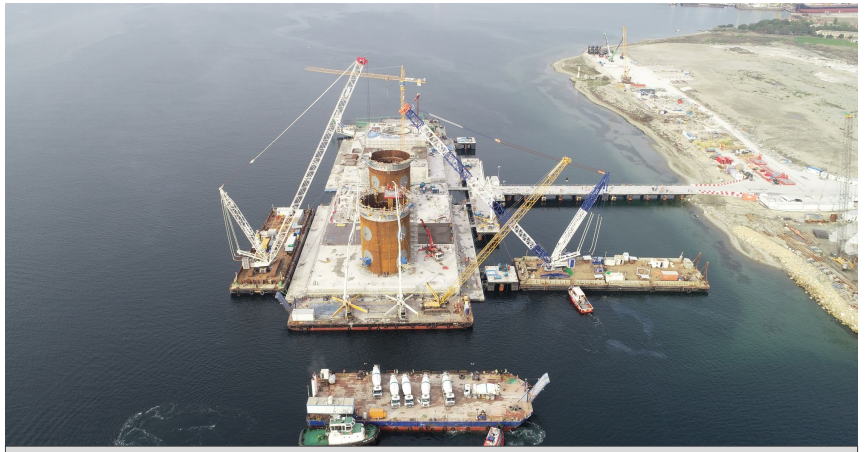
Caisson Fabrication



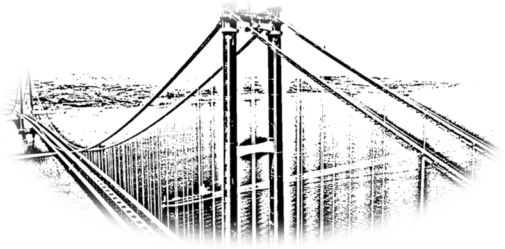
Preparation of dry dock

Caisson fabrication in the dry dock

Floating & Moving the caisson to the wet dock



Steel shaft(for plinth) installation



Tower Foundation

Caisson Towing

Tower Foundation

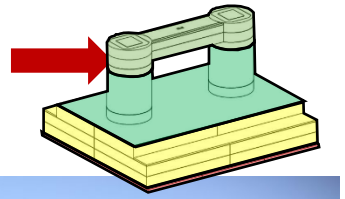
Caisson Immersion

Tower Foundation

Caisson Immersion

Tower Foundation

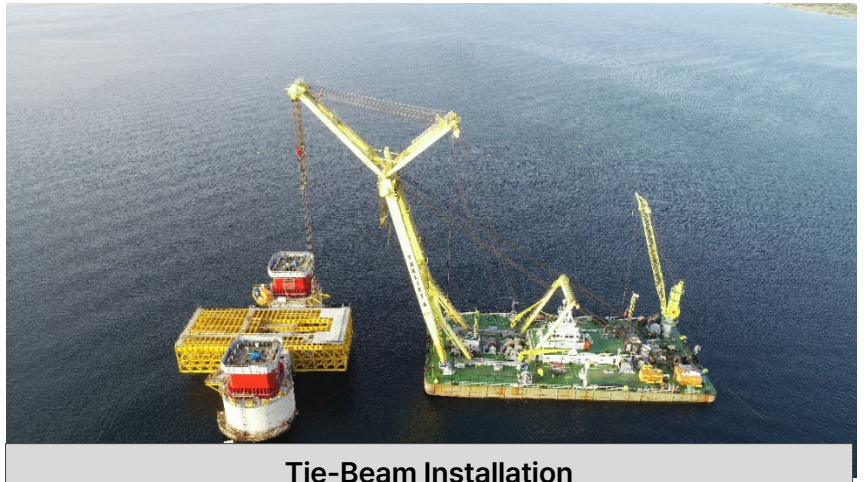
Plinth and Tie- Beam Construction



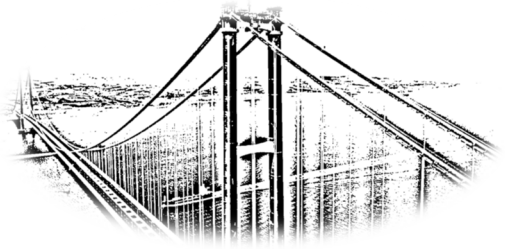
Form/Rebar Cage Pre-Fabrication

Plinth Form/Rebar Cage Installation

Tie-Beam Pre-Fabrication



Tie-Beam Installation



Construction

Tower

Tower

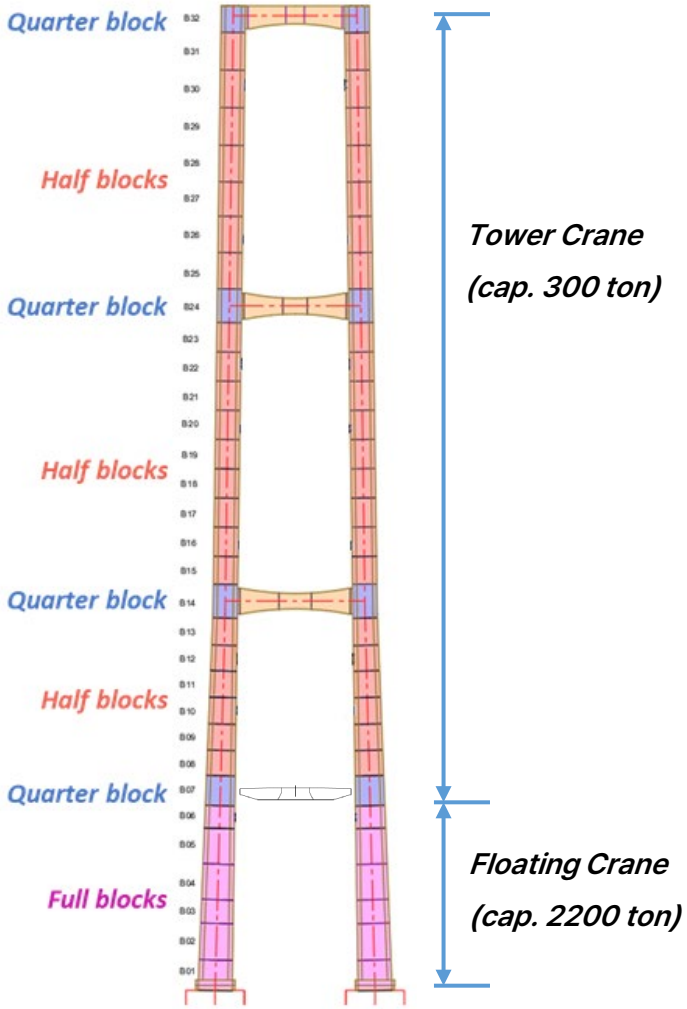
Tower Block Fabrication

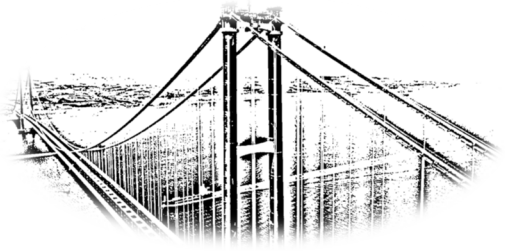
Block Division


Quarter Block


Half Block

Full Block





Tower

Tower Block Fabrication

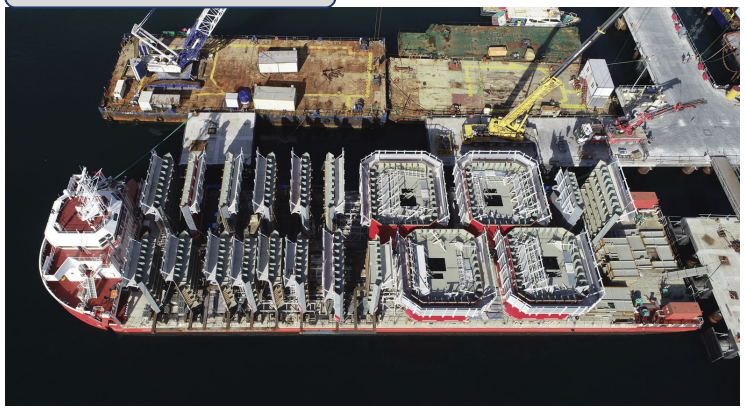
Block Fabrication

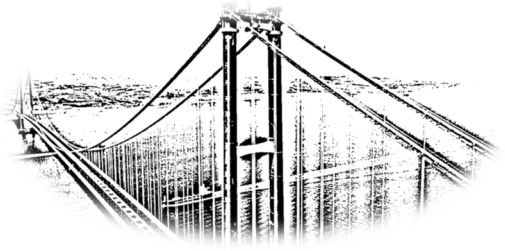
Panel formation

Block formation

Trial assembly

Delivery





Tower

Tower Block Assembly

By Floating Crane

Tower

Tower Block Assembly

Tower Crane Installation

Tower

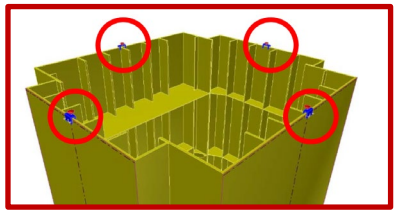
Tower Block Assembly

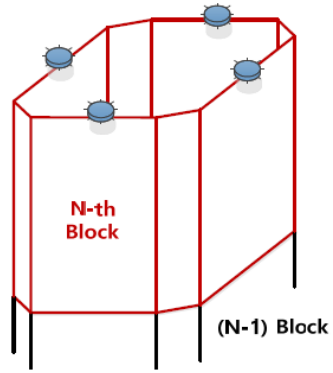
Upper Blocks Lifting by Tower Crane

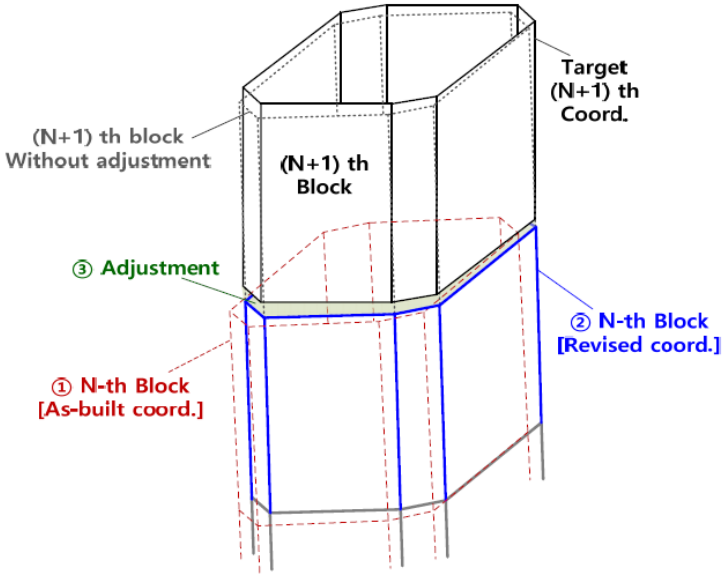
Tower

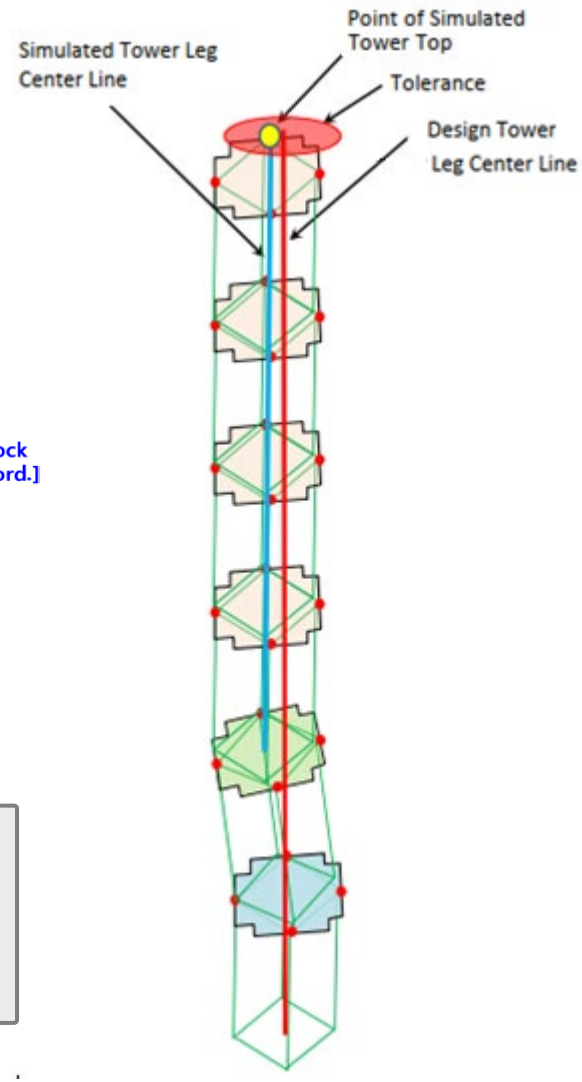
Tower Block Assembly

Geometry Control







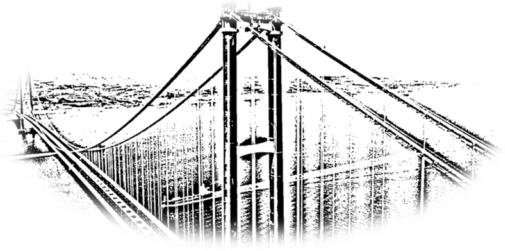


As built survey

By GPS survey,
Identifying the position
with environmental condition
(temp, wind, etc)

Install a new block

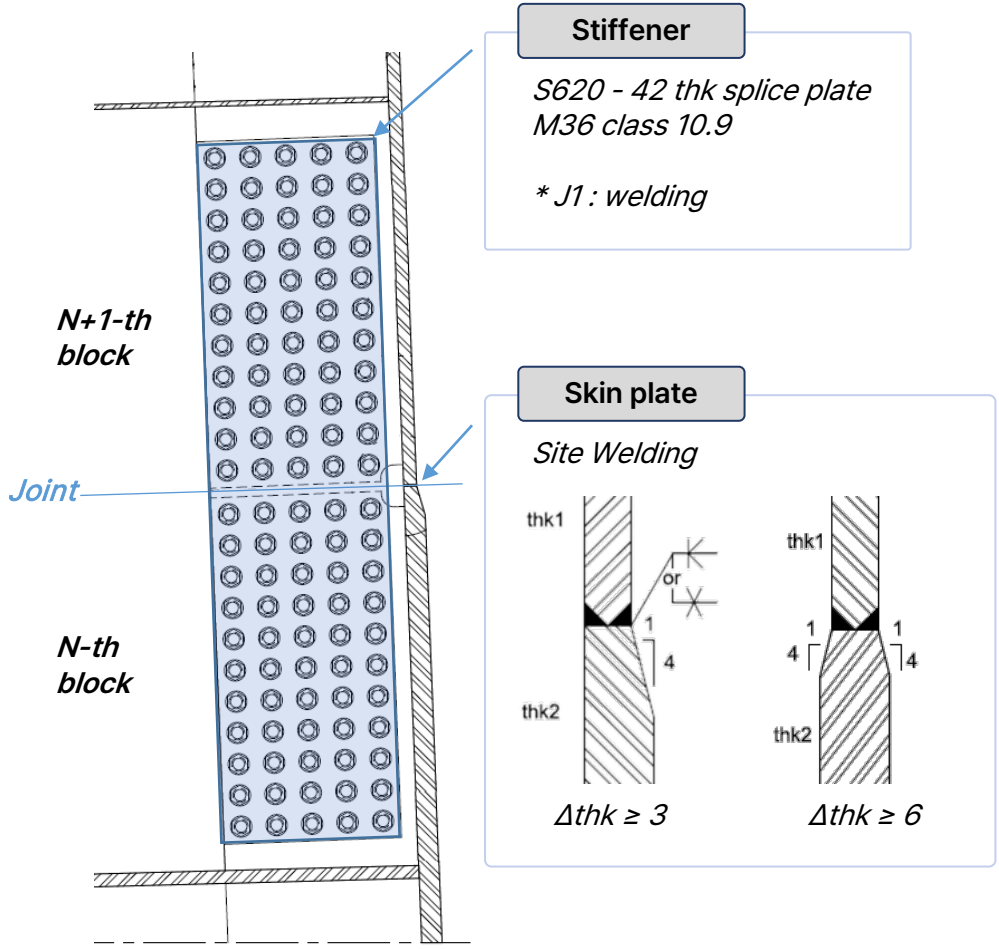
Position is adjusted
by shim plates
according to survey result



Tower

Tower Block Assembly

Connection(Welding & Bolting)



Stiffener

S620 - 42 thk splice plate
M36 class 10.9

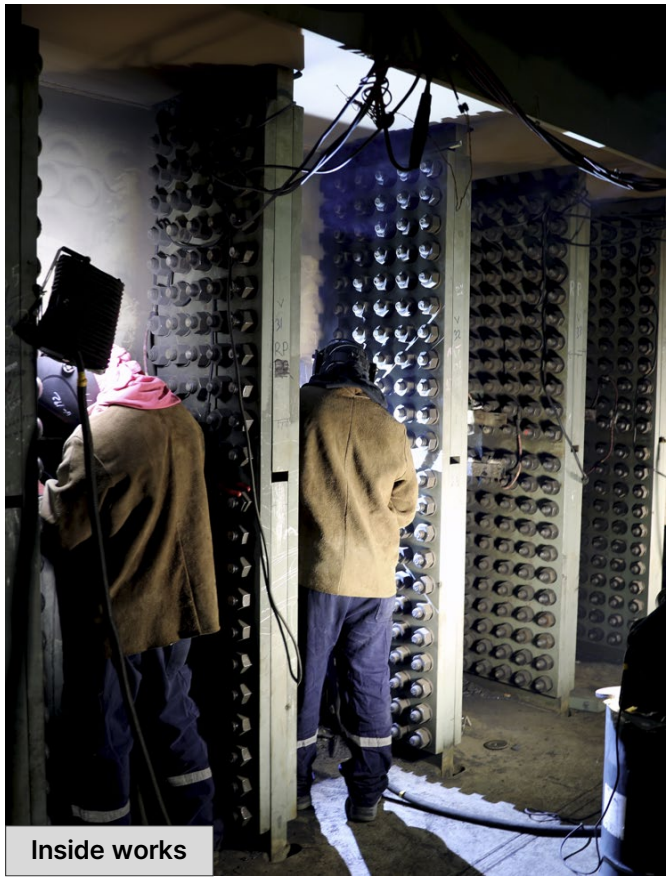
** J1 : welding*

Skin plate

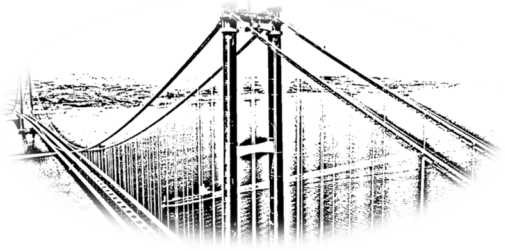
Site Welding

Δthk ≥ 3

Δthk ≥ 6



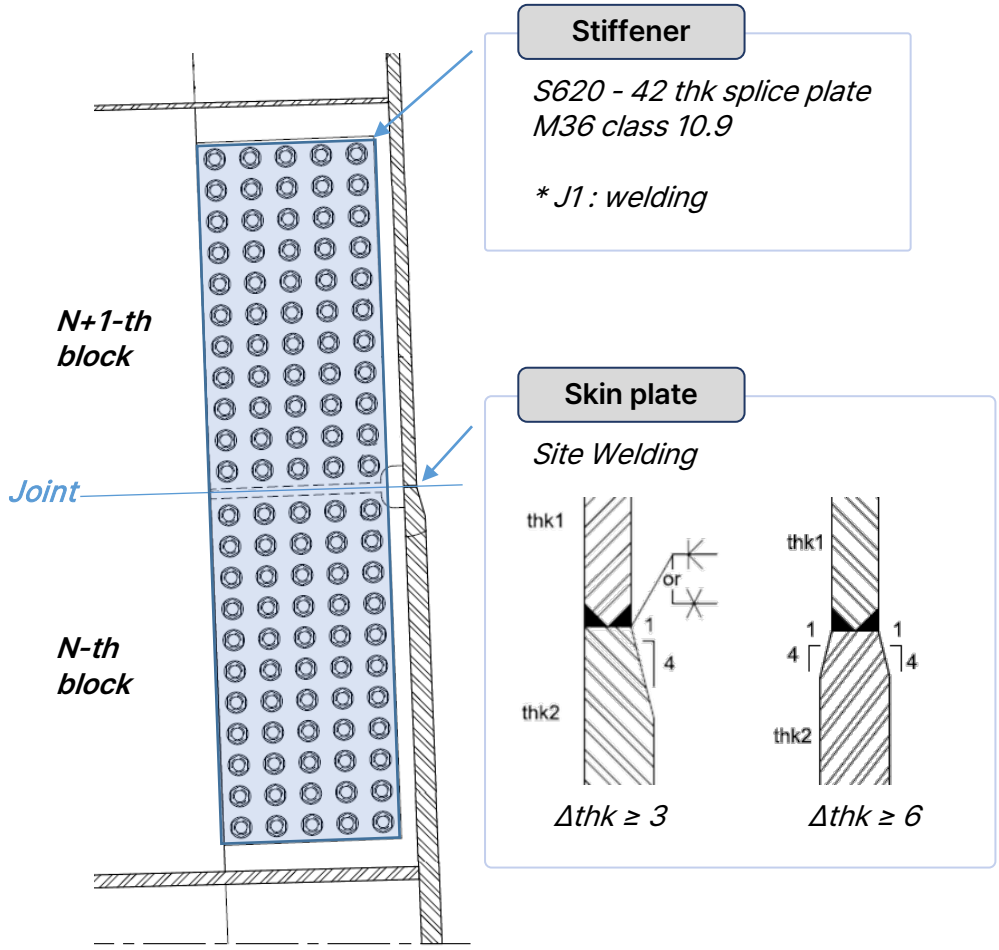
Inside works



Tower

Tower Block Assembly

Connection(Welding & Bolting)



Stiffener

S620 - 42 thk splice plate
M36 class 10.9

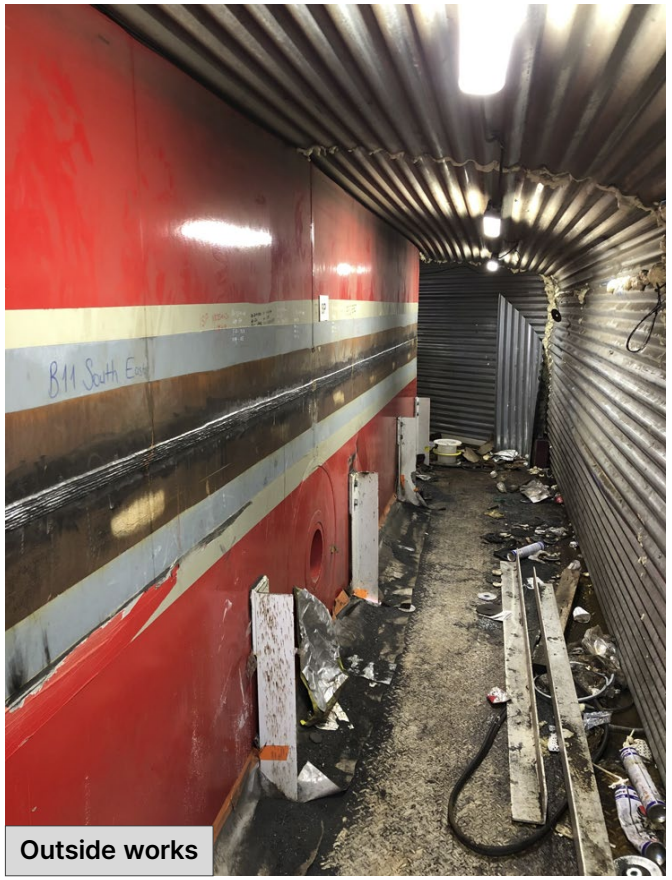
** J1 : welding*

Skin plate

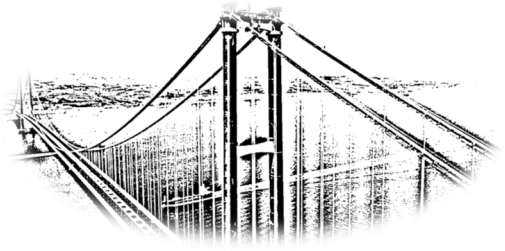
Site Welding

Δthk ≥ 3

Δthk ≥ 6



Outside works



Construction

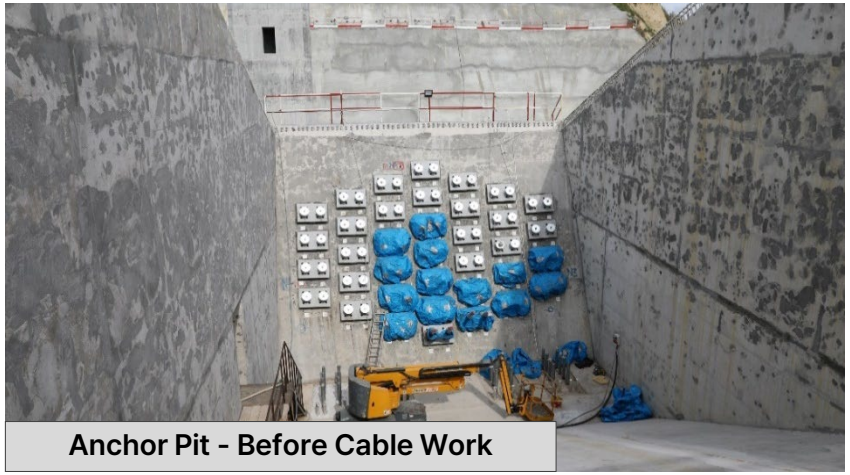
Anchor Block

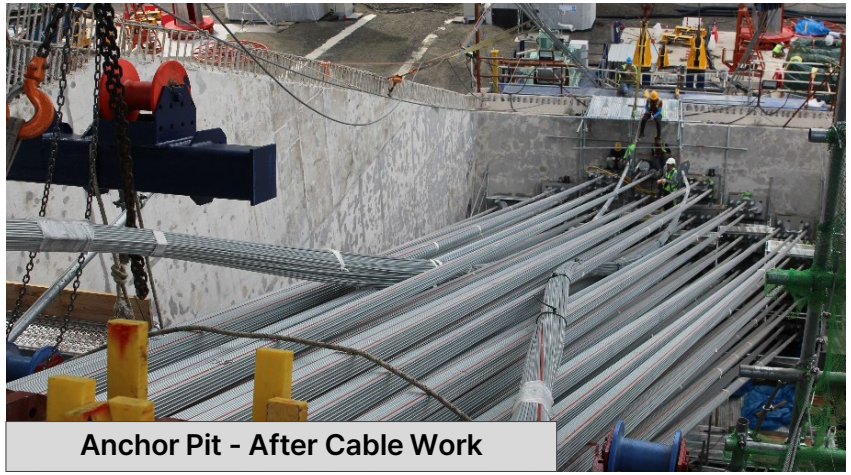
Anchor Block

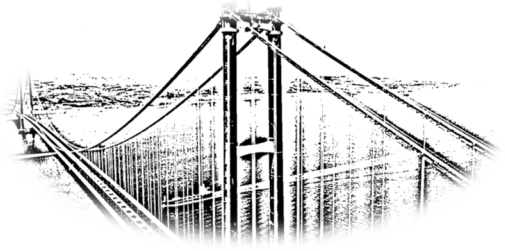
Anchor Block Construction

Anchor Block in EU side


Anchor Block in Asia side


Anchor Pit - Before Cable Work


Anchor Pit - After Cable Work



Construction

Cable

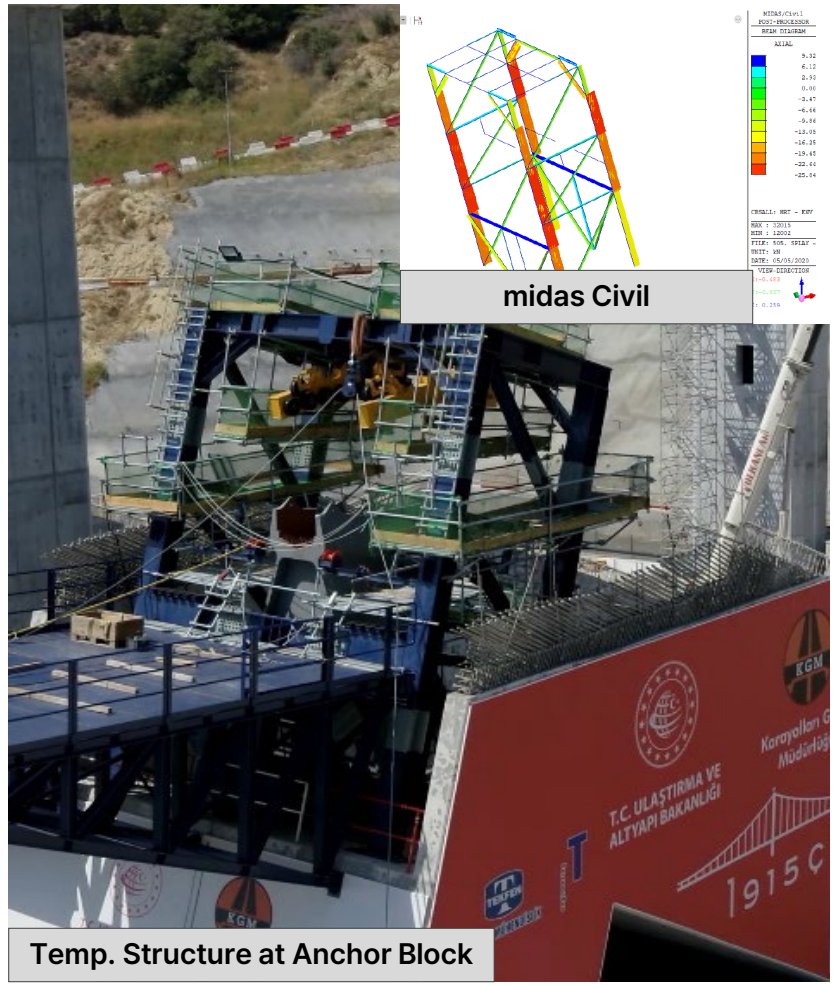
Cable

Temporary Structures

Tower top bent & splay bent

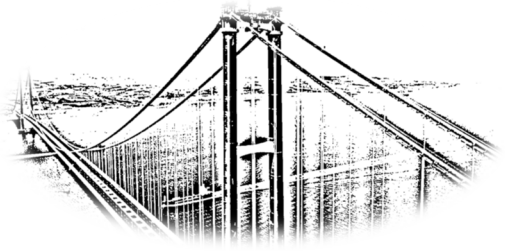
midas Civil

Temp. Structure at Tower Top



midas Civil

Temp. Structure at Anchor Block

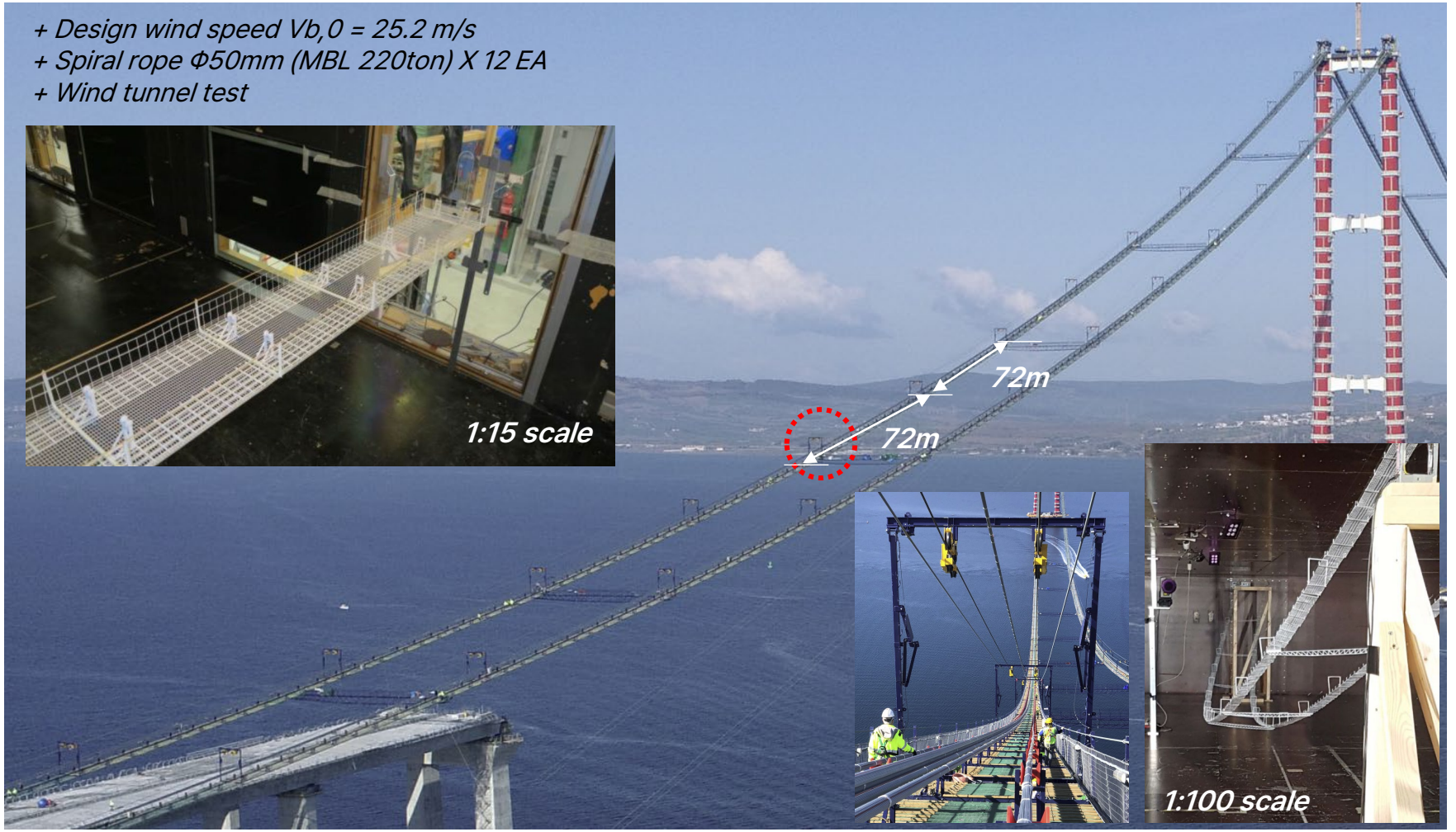


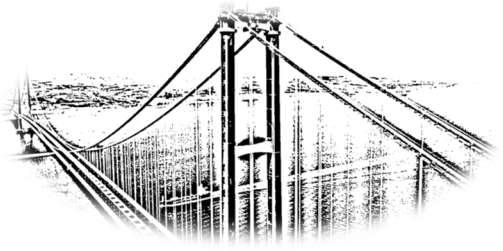
Cable

Temporary Structures

Catwalk system

+ Design wind speed Vb,0 = 25.2 m/s
+ Spiral rope Φ50mm (MBL 220ton) X 12 EA
+ Wind tunnel test

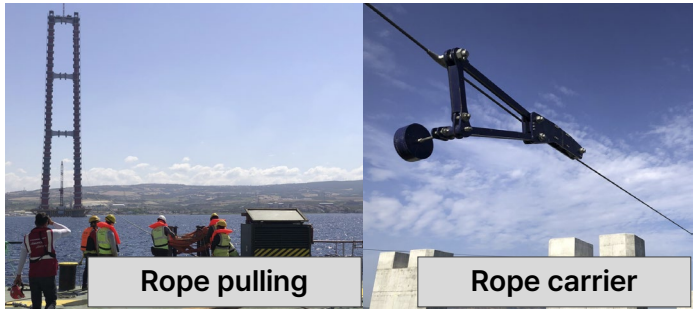


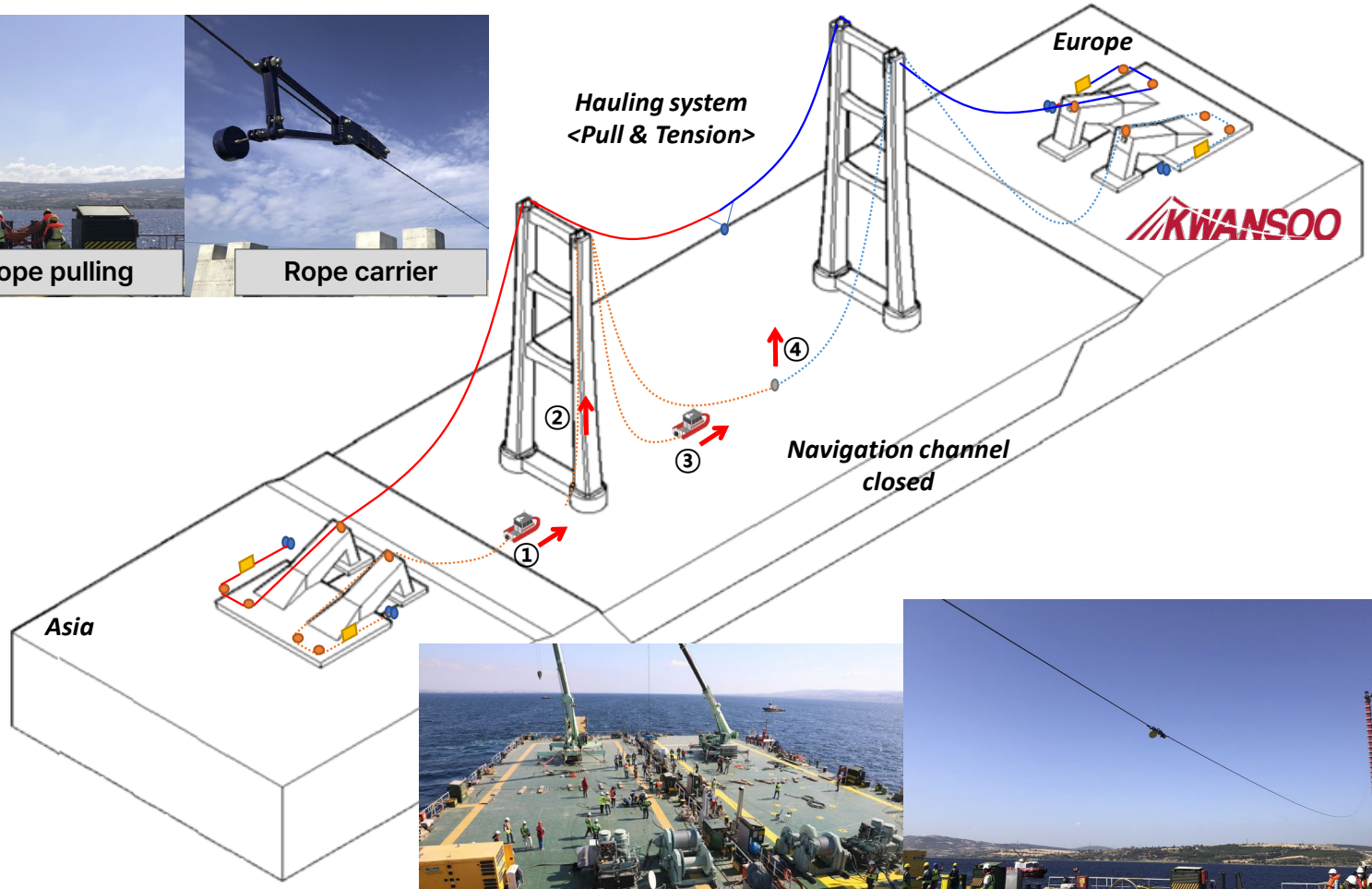


Cable

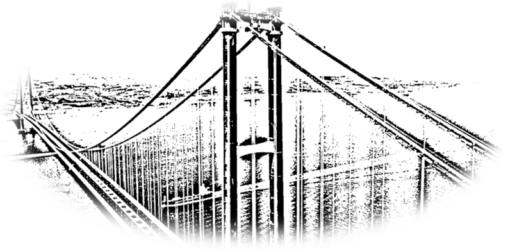
Temporary Structures

Pilot rope






Rope connection

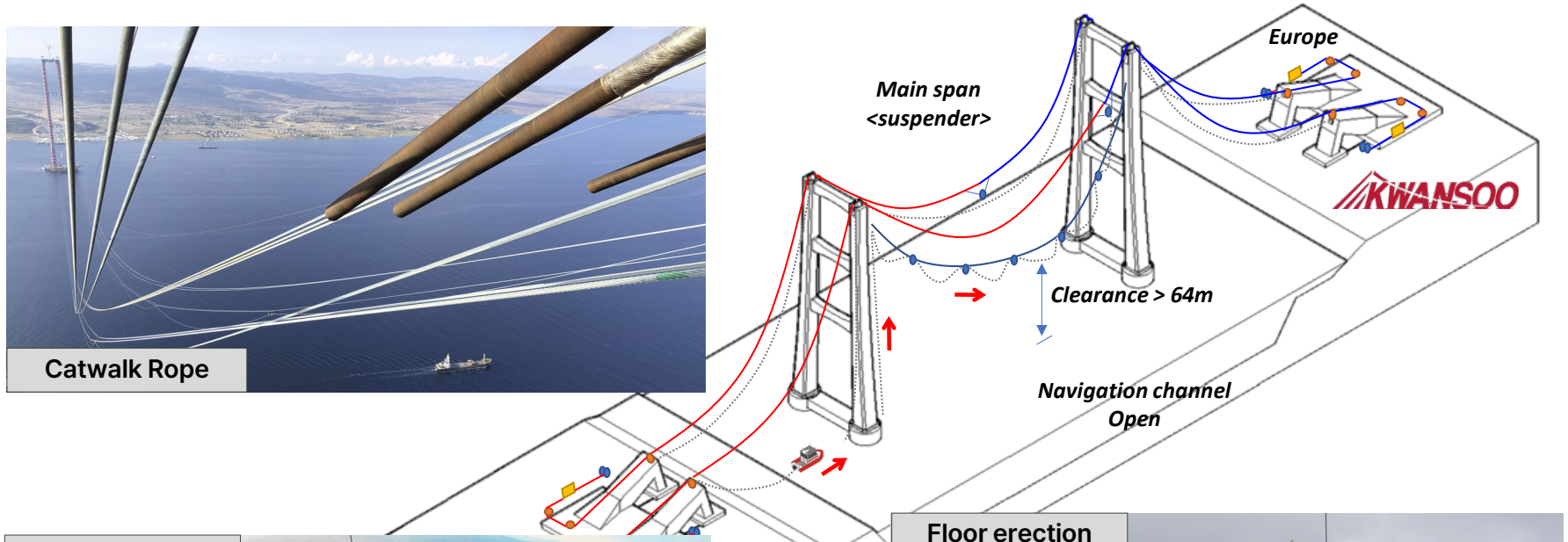


Cable

Temporary Structures

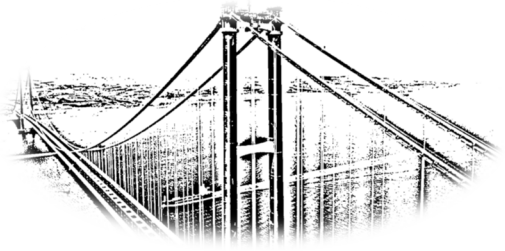
Catwalk installation

Catwalk Rope




Floor erection
(main span)


Floor erection
(side span)

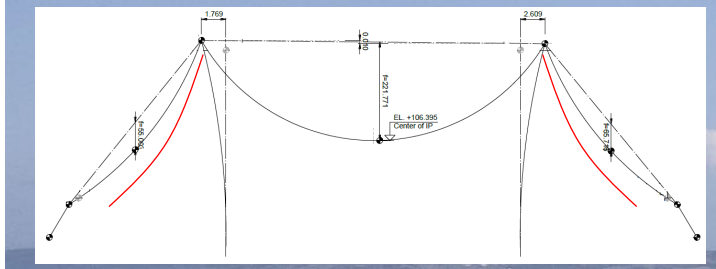


Cable

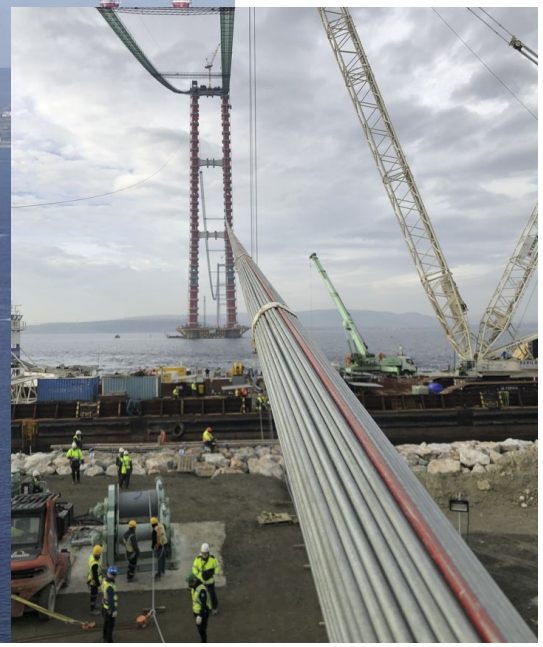
Temporary Structures

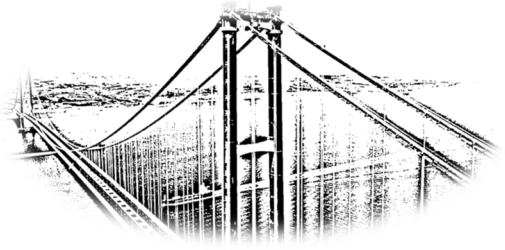
Pull-back system installation

+ Pull-back is required by TWE : 1.7 m / TWA : 2.6 m
+ Φ5.75mm PWS127 x 2EA / tower leg



+ Required tension
- TWE : 70 ton per strand
- TWA : 100 ton per strand



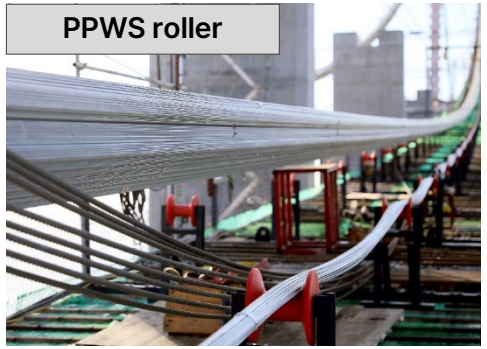


Cable

Main Cable Erection

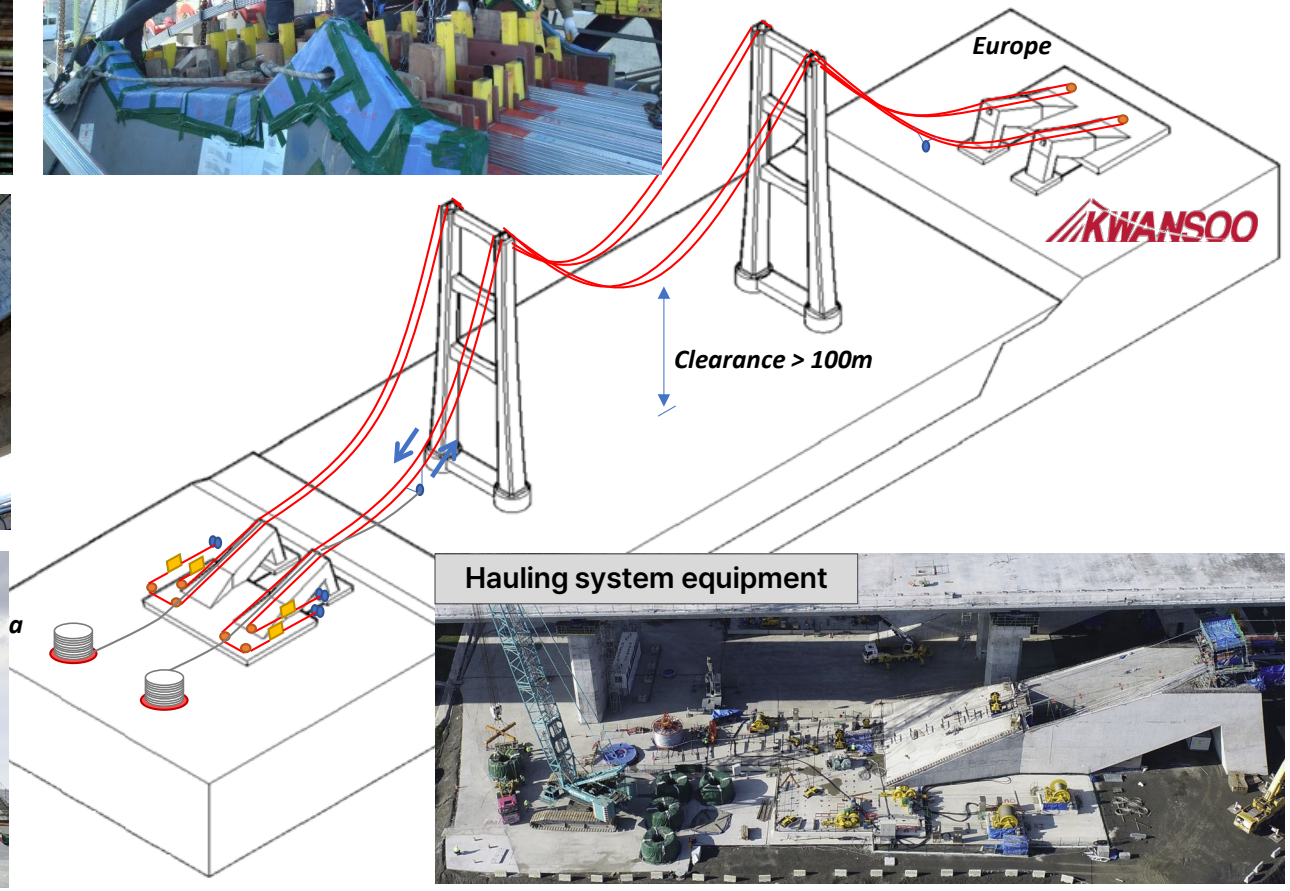
PPWS erection

PPWS roller



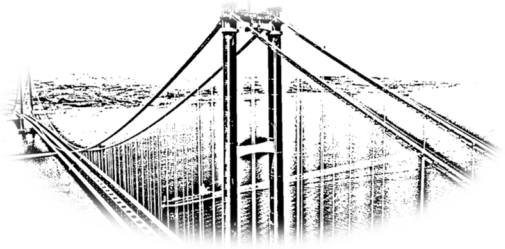
Saddle inserion

PPWS carrier



PPWS supply

Hauling system equipment



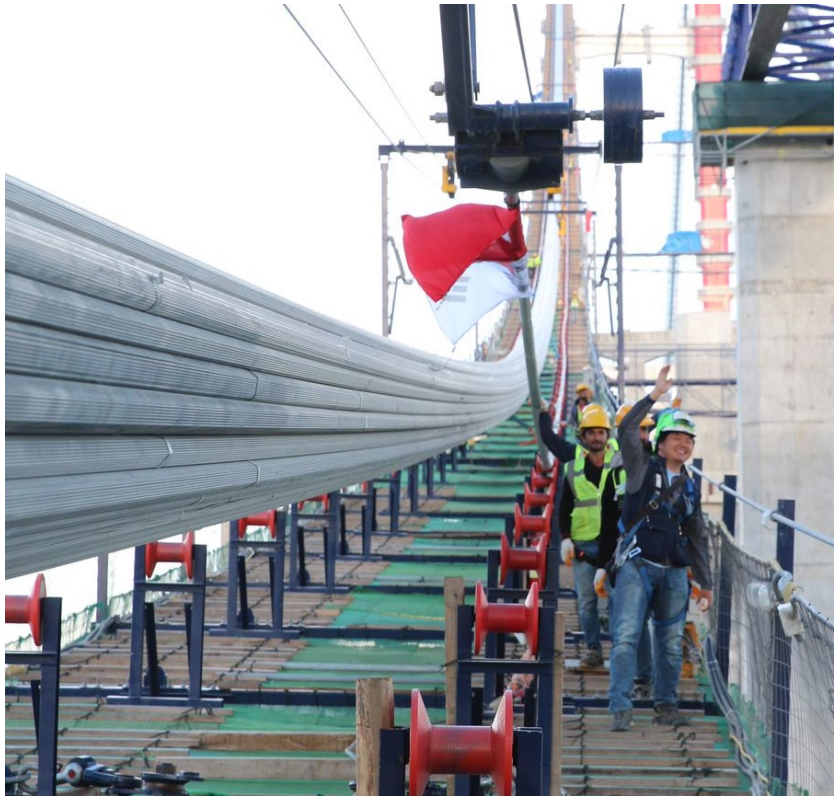
Cable

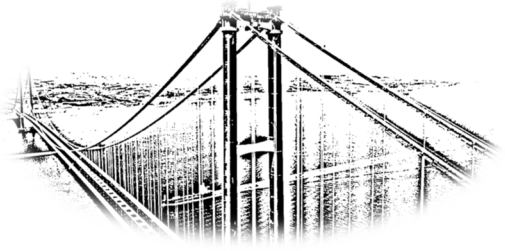
Main Cable Erection

PPWS erection

The first strand(No.1)
2021. 2. 4

The last strand(No. 144)
2021. 5. 20

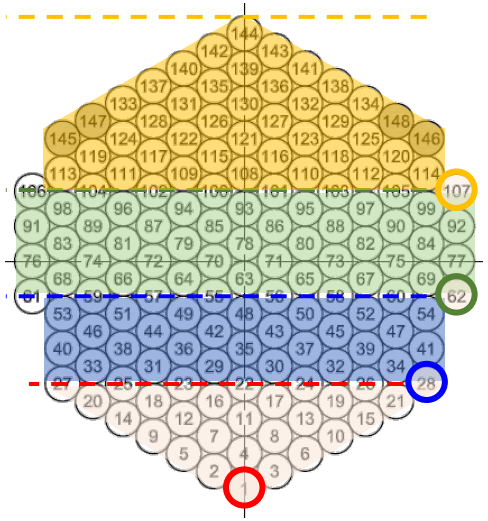


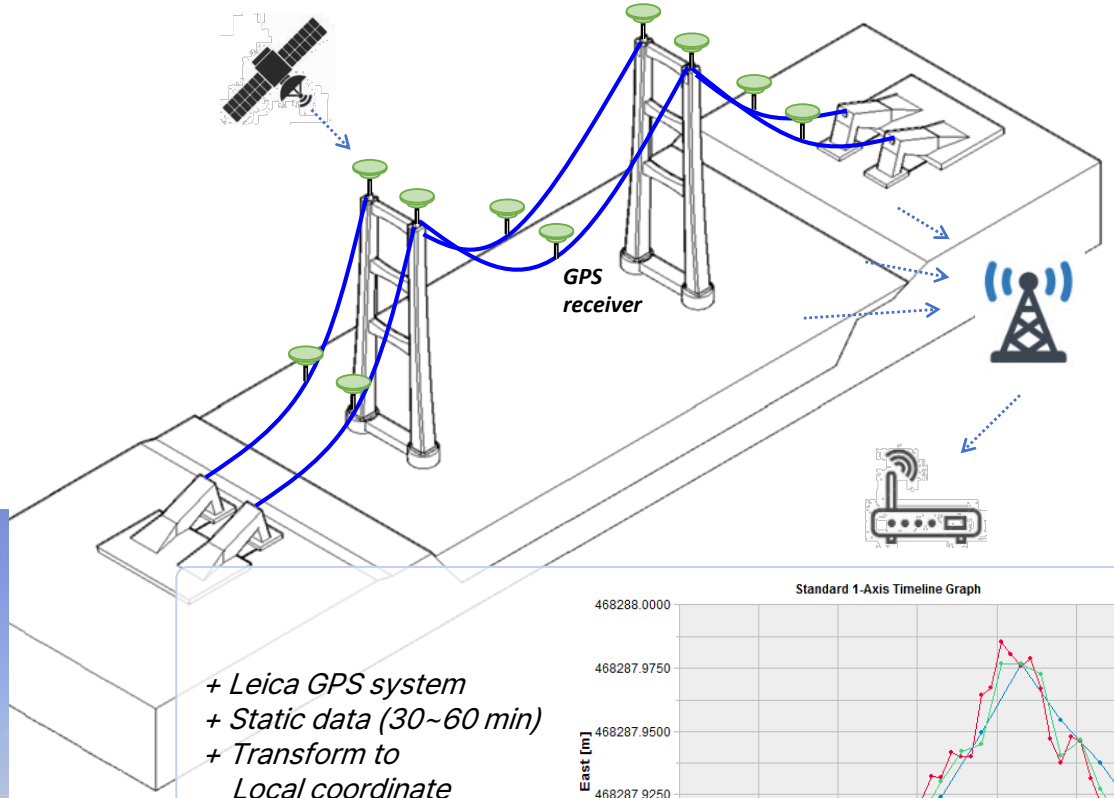


Cable

Main Cable Erection

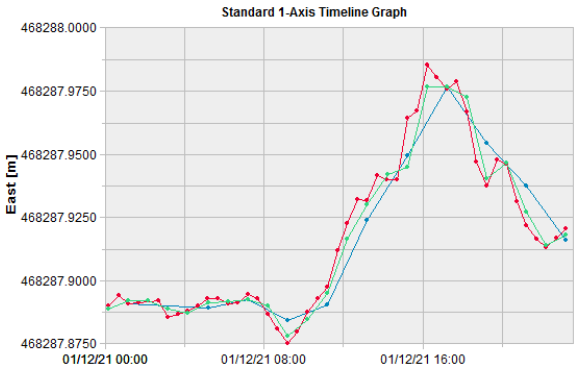
Geometry control

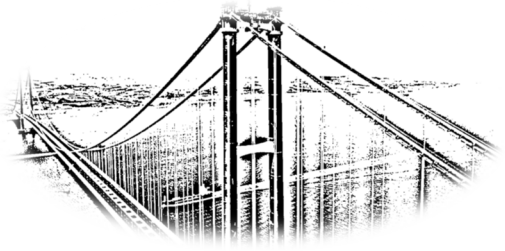




+ Leica GPS system
+ Static data (30~60 min)
+ Transform to
Local coordinate

+ 23:00 – 6:00 (+1 day)



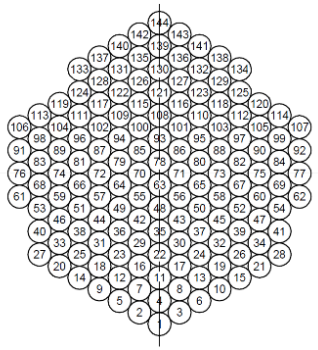


Cable

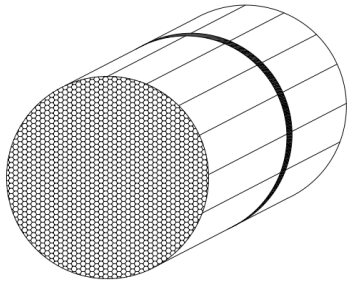
Main Cable Erection

Cable compaction

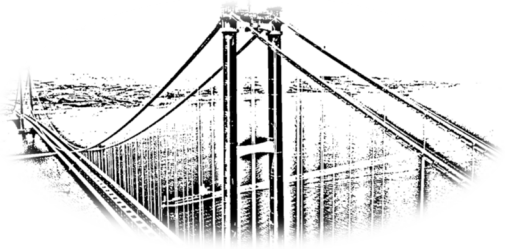
Before compaction



After compaction



	Void Ratio	Diameter
General Section	~20%	Main: 869 mm
		Side: 881 mm
Clamp Section	17 ± 2 %	Main: 854 mm
		Side: 865 mm



Cable

Main Cable Erection

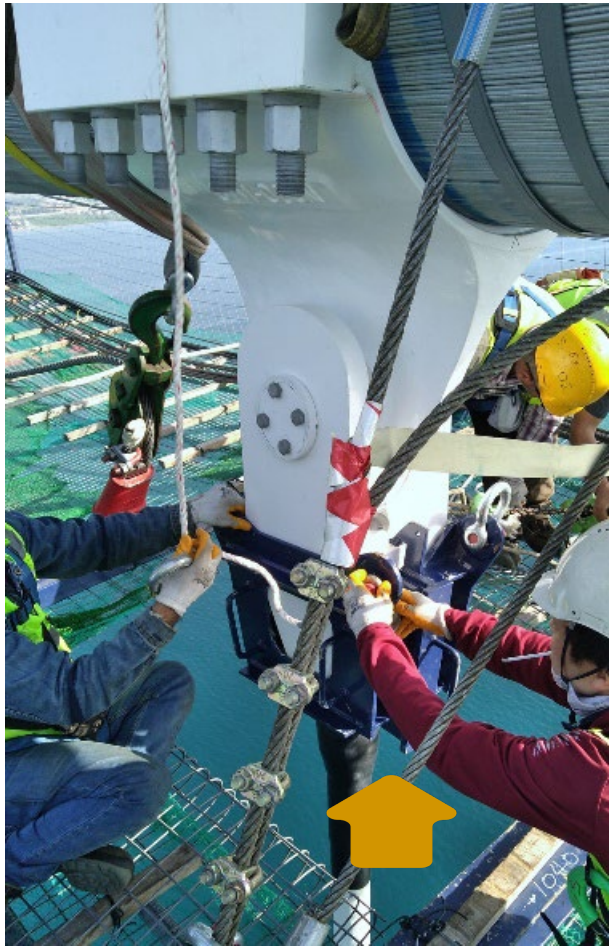
Cable clamp

Cable

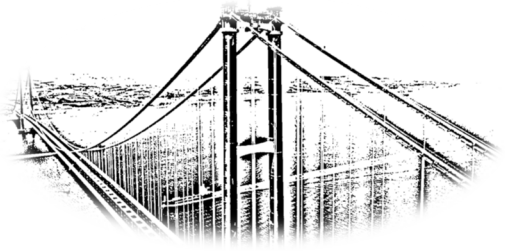
Main Cable Erection

Hanger cable installation

Hanger lifting



Hanger connecting



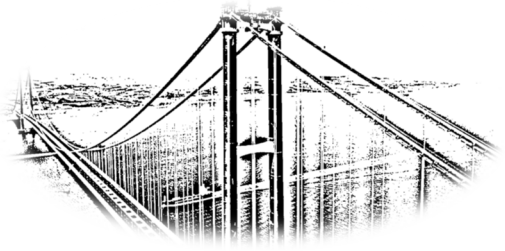
Cable

Main Cable Erection

Main cable wrapping

Round wire wrapping

Elastomeric band wrapping



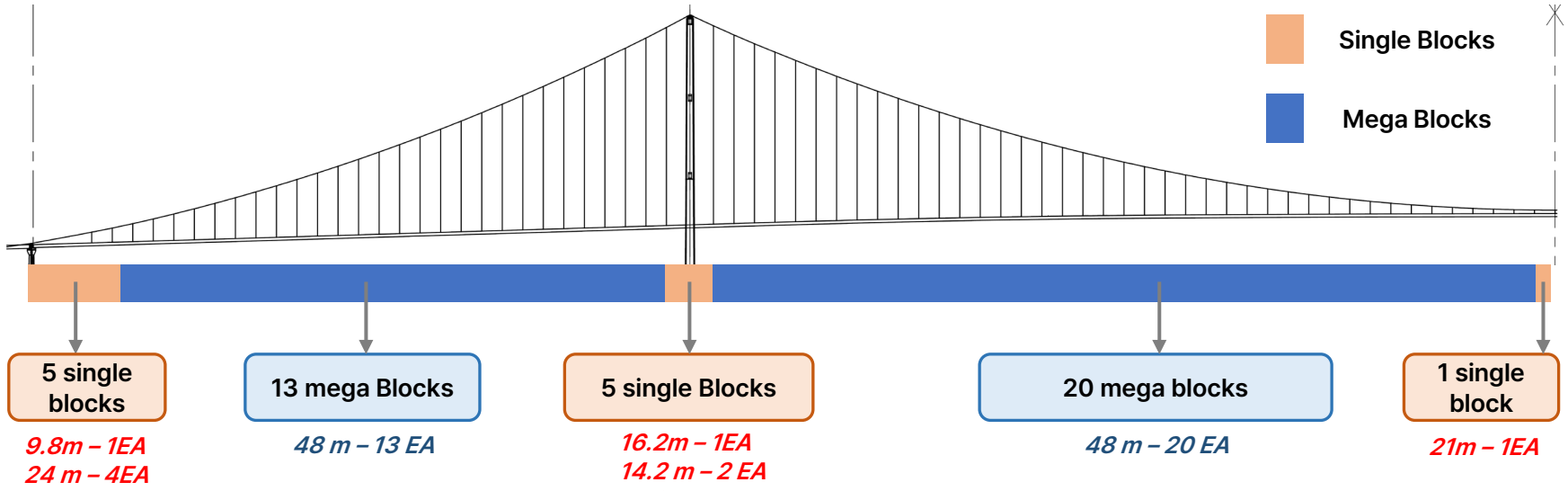
Construction

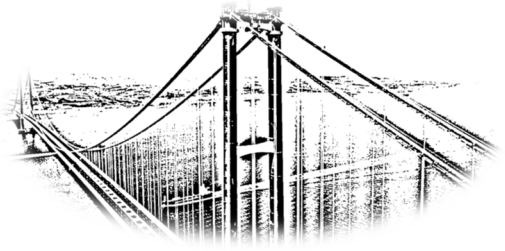
Deck

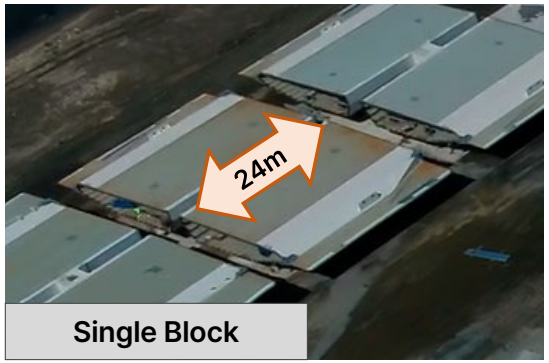
Deck

Deck Fabrication

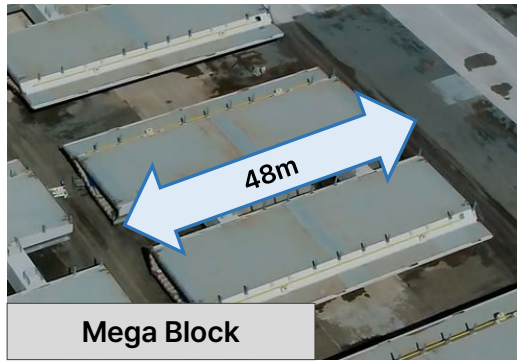
Deck Block Division







Single Block



Mega Block

Deck

Deck Fabrication

Factory Manufacturing

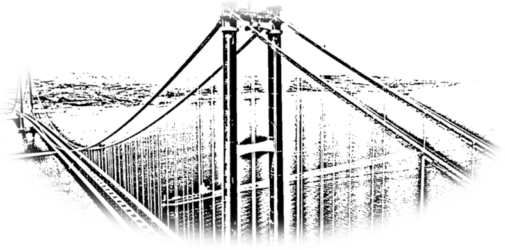
Panel formation (5 panels)


Segment formation (24m)


Trial assembly (48m)

Delivery

Stock yard

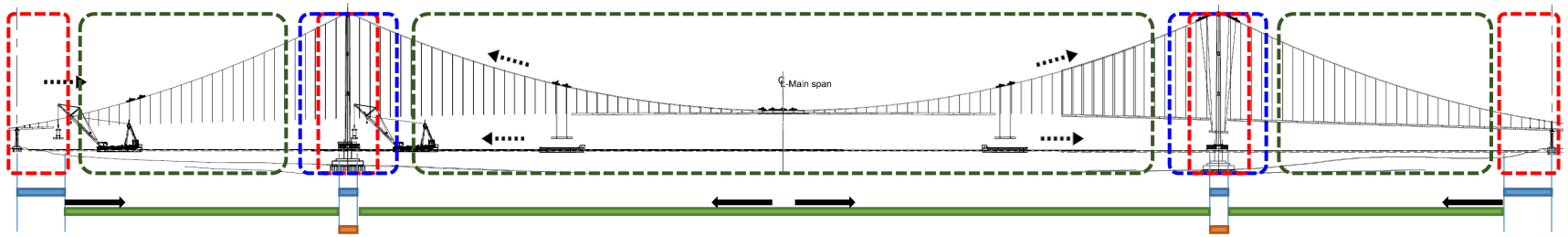



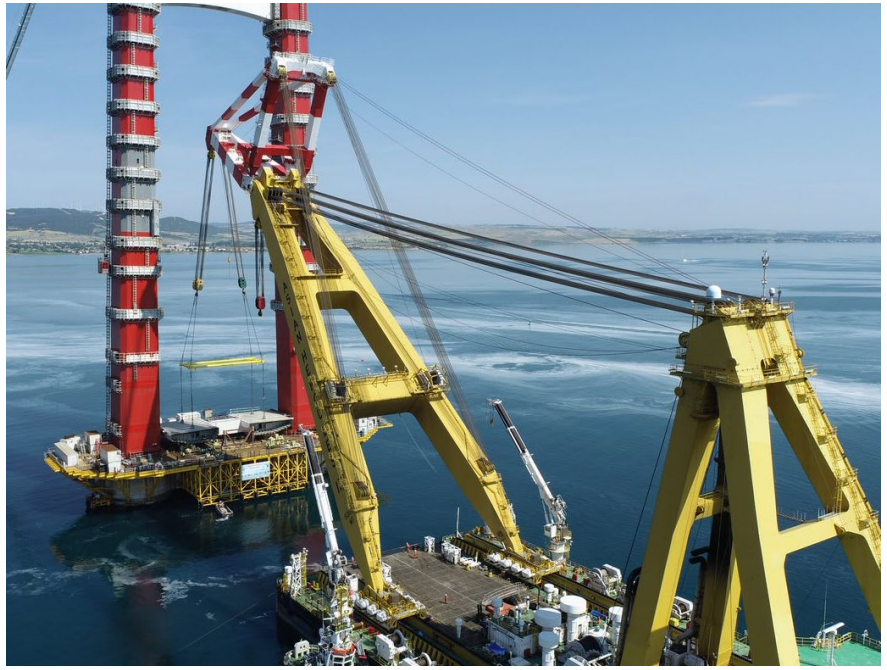
Deck

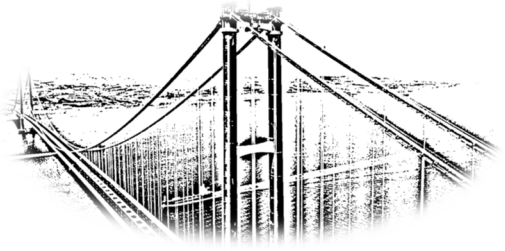
Deck Erection

Erection Sequence - Phase 1

Phase 1 : FC operation (Single block) Phase 2 : LG operation (Double & Single block) Phase 3 : LG operation (Key segment) - Triple block





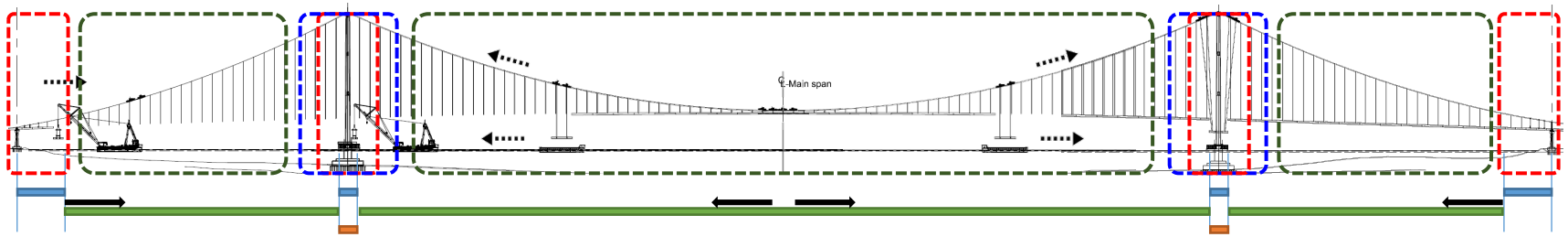


Deck

Deck Erection

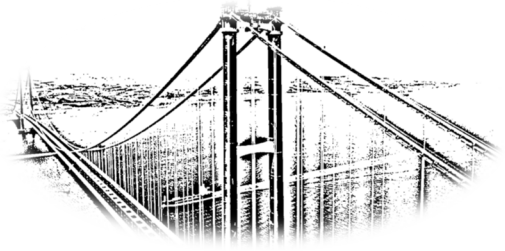
Erection Sequence - Phase 2

Phase 1 : FC operation (Single block) Phase 2 : LG operation (Double & Single block) Phase 3 : LG operation (Key segment) - Triple block




L/G Self Erection


L/G Installation on cables

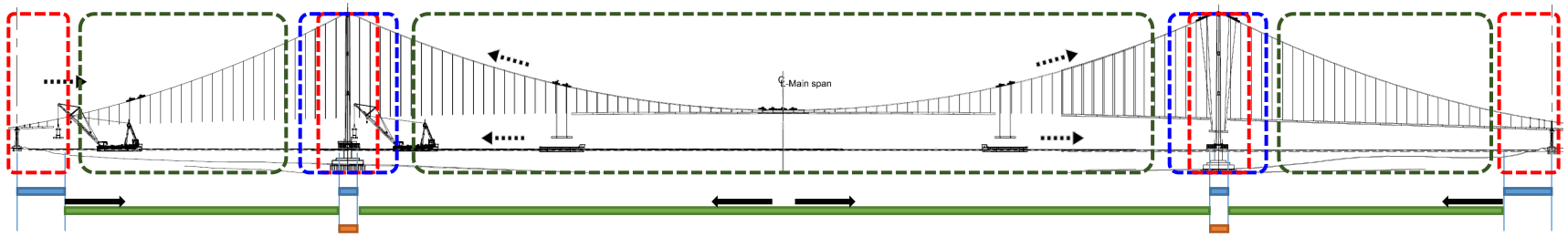


Deck

Deck Erection

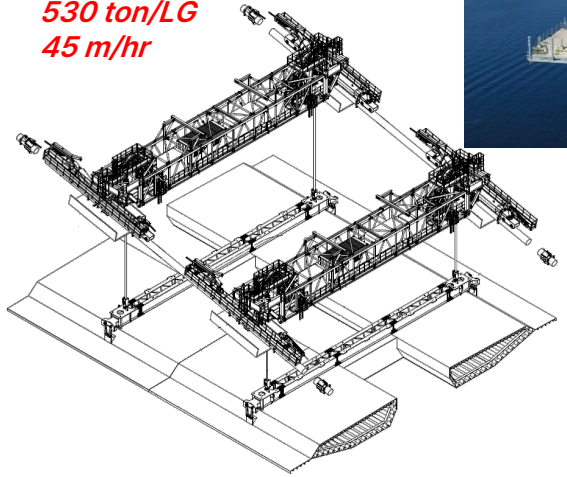
Erection Sequence - Phase 2

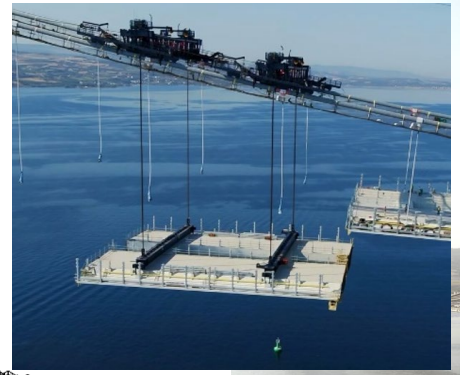
Phase 1 : FC operation (Single block) Phase 2 : LG operation (Double & Single block) Phase 3 : LG operation (Key segment) - Triple block



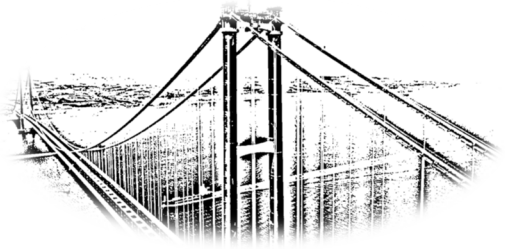
Weight, 255 ton/LG

Lifting,
530 ton/LG
45 m/hr





L/G Installation on cables

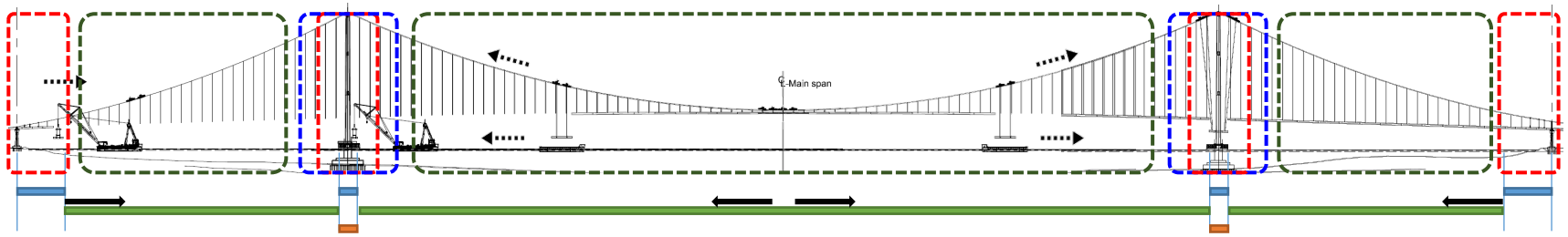


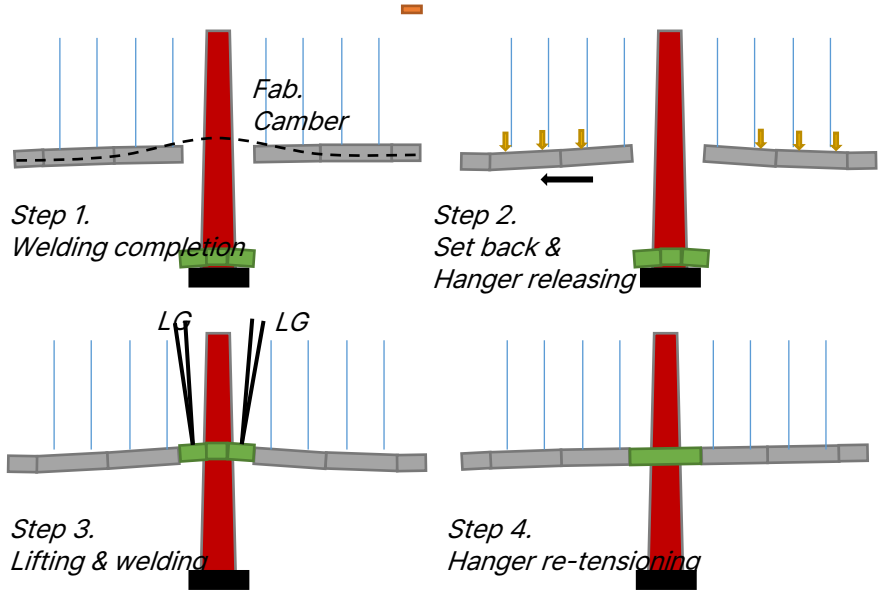
Deck

Deck Erection

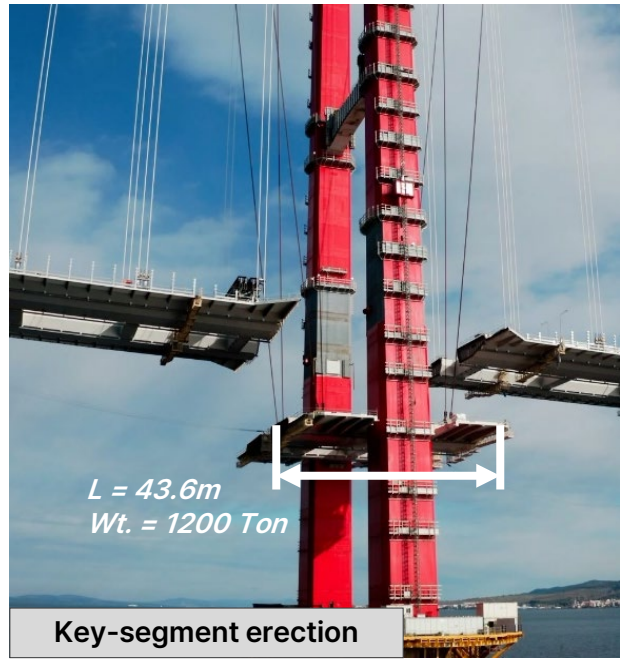
Erection Sequence - Phase 3

Phase 1 : FC operation (Single block) Phase 2 : LG operation (Double & Single block) Phase 3 : LG operation (Key segment) - Triple block

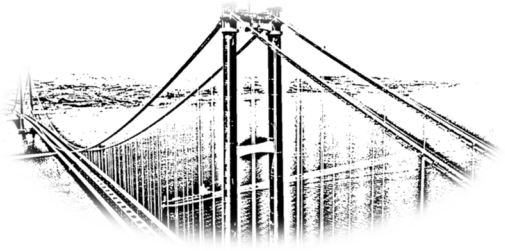




Key-segment

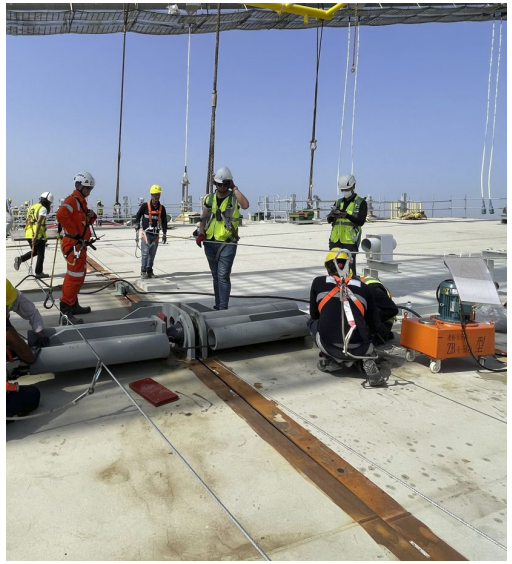


Key-segment erection



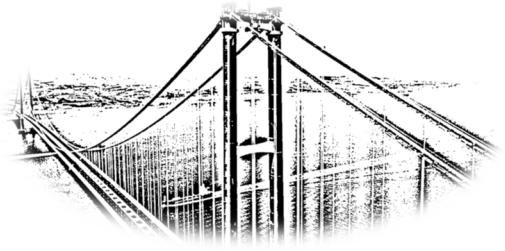
Deck

Deck Welding



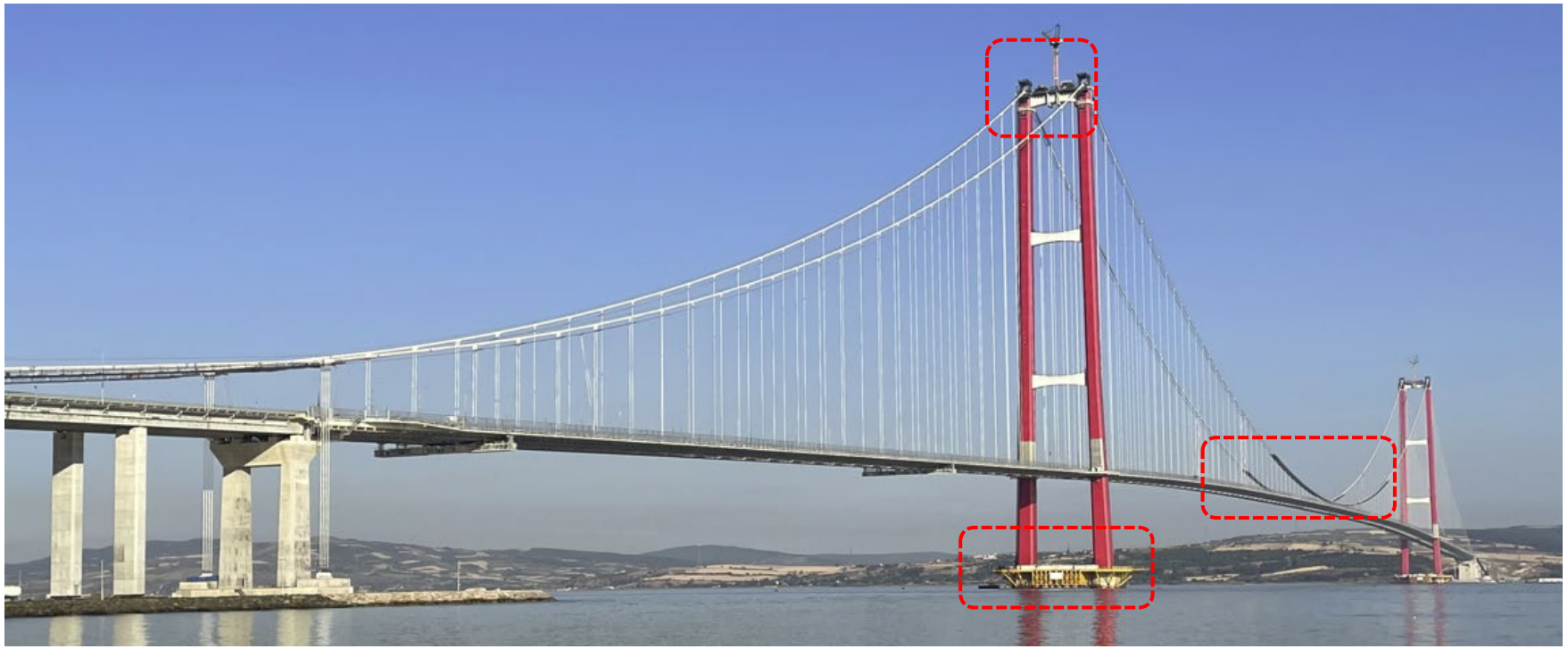
Completion

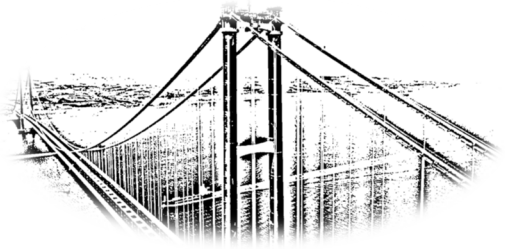
Bridge Opening



Completion

Dismantling Temporary Structures





Summary

Summary

As a DEVELOPER for PPP project,

+ Success in planning and financing of mega-scale overseas projects(3.1B EUROS)

+ Risk analysis and prevention plan established at contract stage

+ Secure profits through financial planning for the entire project period(16yrs)

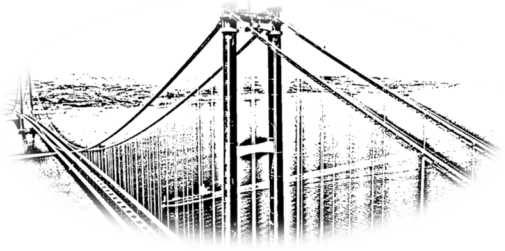
As an EPC contractor for the longest suspension bridge,

+ Parallel design-construction according to time constraints (FAST-TRACK)

+ Risk analysis and safety evaluation of vehicle load and environmental factor load

+ Procurement of high-strength/high-quality materials from around the world

+ Proving technological prowess by leading Construction Engineering



Summary

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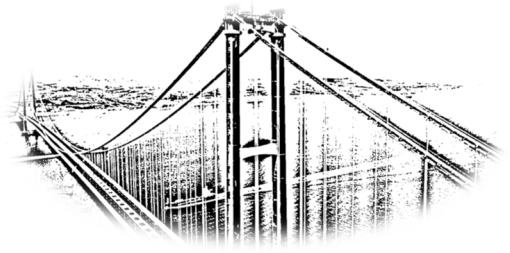

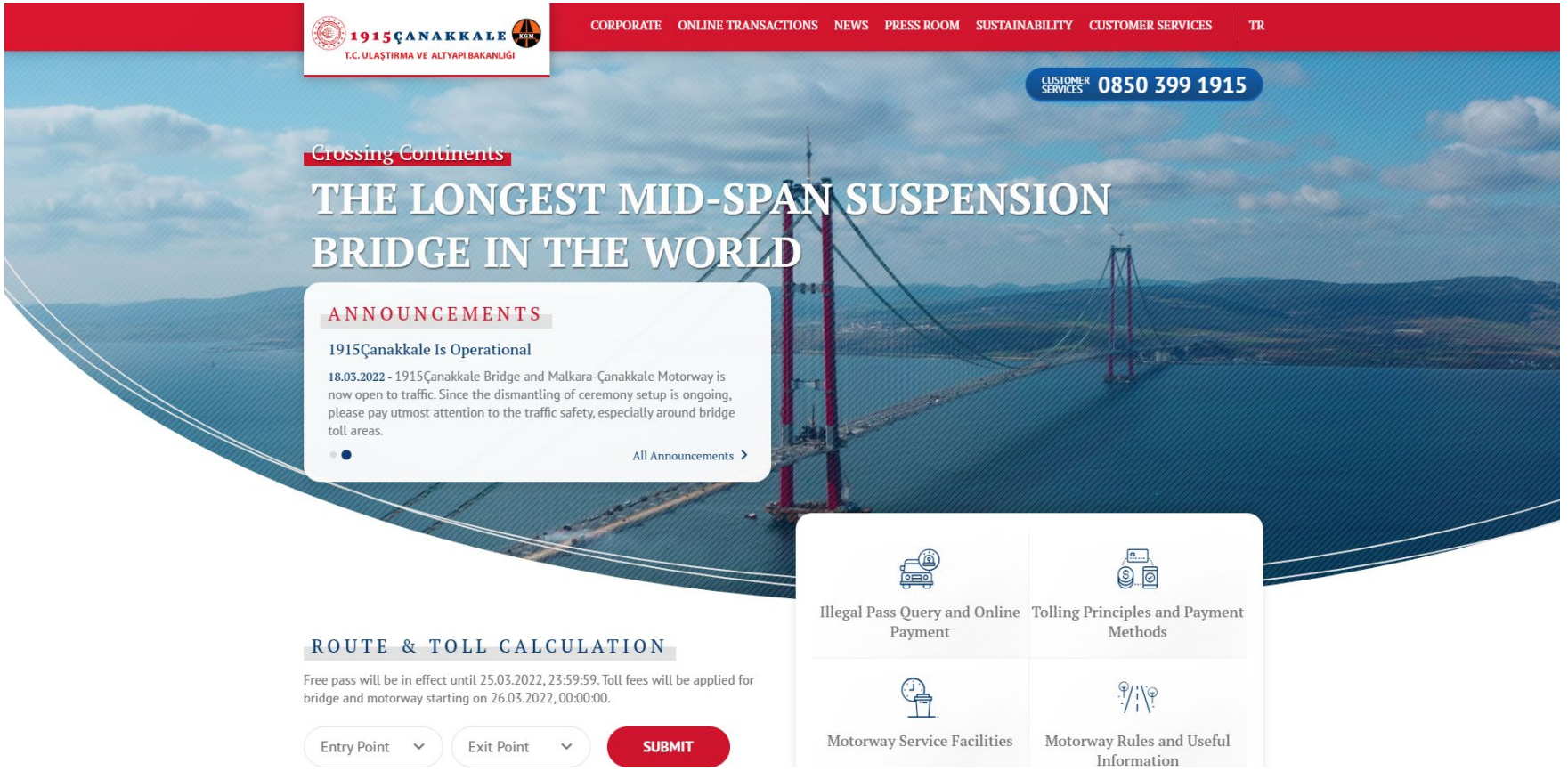

Summary

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