La Construccion del Puente sobre el Canal en el lado Atlántico

Fuente: Autoridad del Canal de Panamá

Puente sobre el Canal en el lado Atlántico

Objetivos – Marco Legal & Social

Fuente: Autoridad del Canal de Panamá

Puente sobre el Canal en el Atlántico

- **OBJETIVO DEL PROYECTO:**

Cumplir con la Ley 28, del 17 de julio del 2006, que aprueba la propuesta de construcción del Tercer Juego de Esclusas en el Canal de Panamá, y dispone que la ACP debe desarrollar los estudios necesarios para identificar la opción más conveniente, a fin de establecer un cruce vehicular, ya sea puente o túnel, en el extremo Atlántico del Canal de Panamá, que la construcción debe iniciarse, a más tardar, inmediatamente después de concluido el Tercer Juego de Esclusas, y que el costo de la obra deberá ser cubierto por la ACP.

Marco Legal-Social

- La Autoridad del Canal de Panamá incorpora en su visión corporativa: Constituirse en piedra angular e impulsora del progreso, desarrollo y crecimiento de Panamá

- La Autoridad del Canal de Panamá incorpora en su misión corporativa: Aportar riqueza a Panamá y contribuir con su gestión al bienestar, desarrollo, progreso y mejoramiento de la calidad de vida de todos los panameños

OBJETIVOS DEL PROYECTO

- **Permitir un cruce ininterrumpido, rápido y seguro entre el sector Este y Oeste de la Provincia de Colón**
- **Reducir los tiempos de viaje existentes**
- **Limitar la interferencia con las operaciones del Canal a mínimas o inexistentes**
- **Permitir el transito de buques post-panamax en ambos sentidos**
- **Considerar y permitir futuras expansiones del Canal (cuarto juego de esclusas)**
- **Considerar el diseño del tráfico para futuros desarrollos**

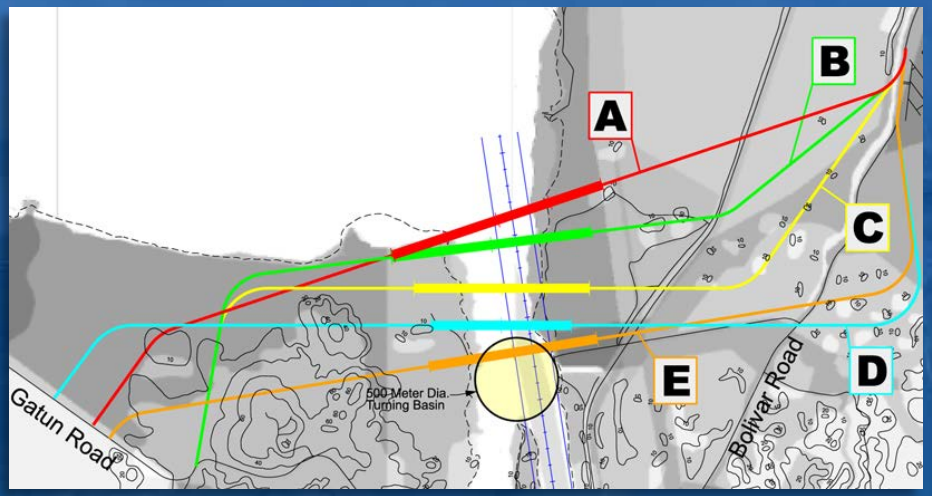
Puente sobre el Canal en el lado Atlántico

Estudios

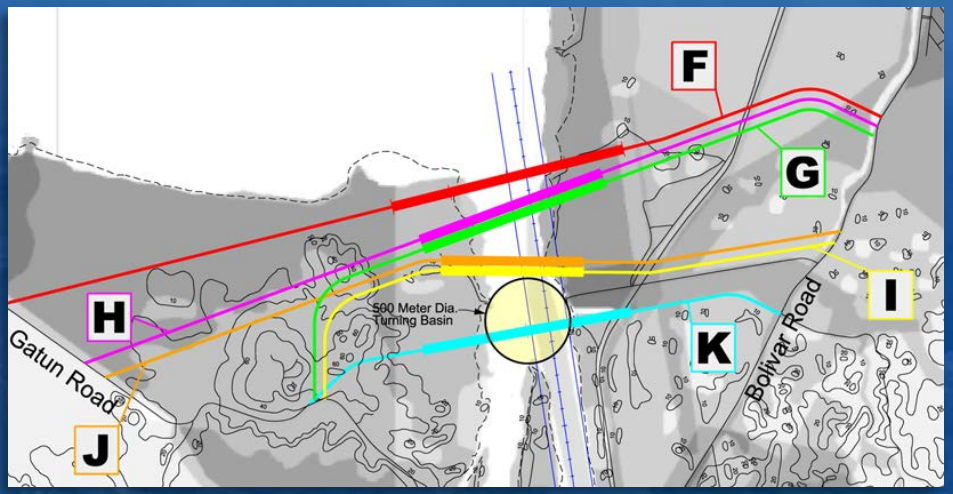
Fuente: Autoridad del Canal de Panamá

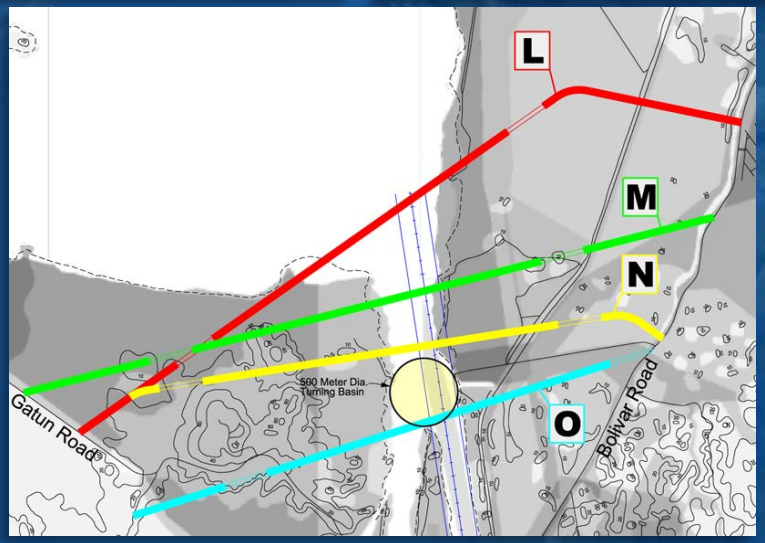
Estudio de Factibilidad

Puente 4%



Puente 5%





Túnel 5%

ESTUDIO DE FACTIBILIDAD

Alineamientos Recomendados

Alineamiento B

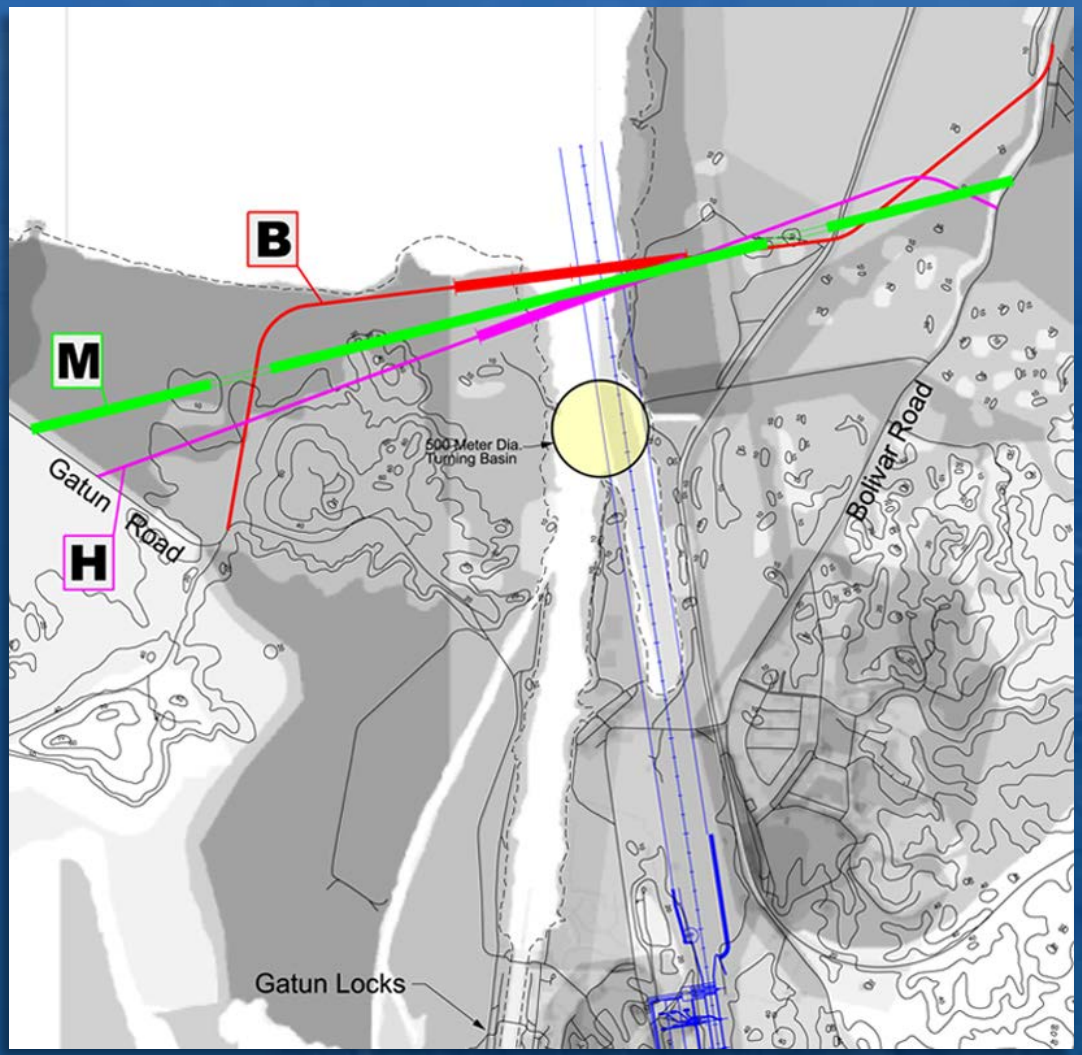
- Puente con pendiente de 4%

Alineamiento M

- Túnel con pendiente de 4%

Alineamiento H

- Puente con pendiente de 5%



Puente sobre el Canal en el lado Atlántico

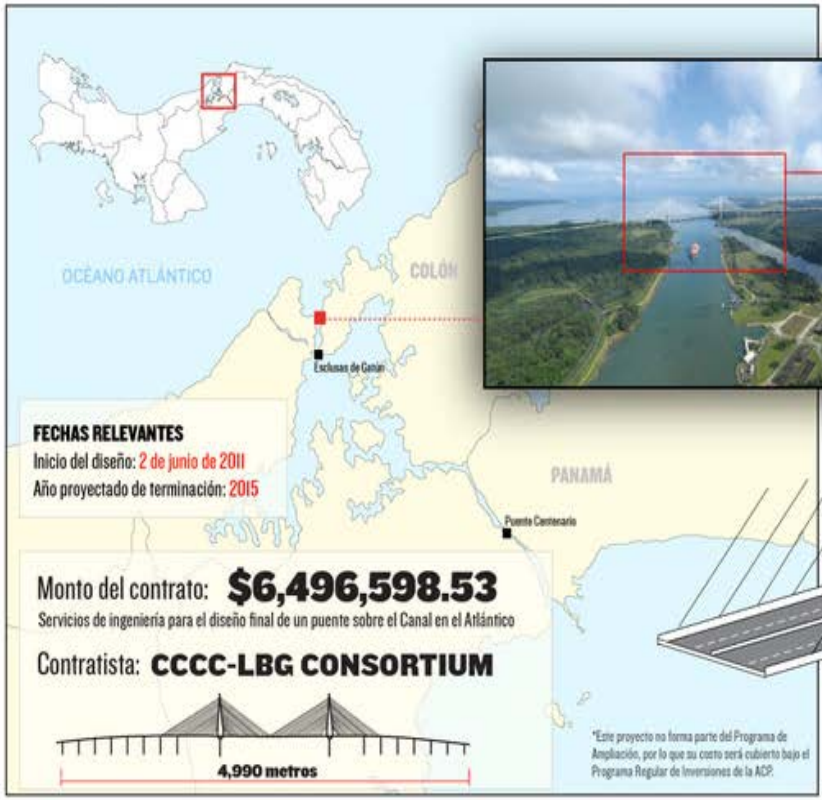
Fase de Diseño

Fuente: Autoridad del Canal de Panamá

Solución Técnica (Diseño)

PROYECTO DE TERCER PUENTE SOBRE EL CANAL DE PANAMÁ

El proyecto consiste en el diseño y construcción de un puente vehicular doble atirantado de concreto y sus accesos, ubicado sobre el Canal en el Atlántico, provincia de Colón. Contempla la conexión de la aproximación oeste del puente con la carretera existente hacia la costa abajo de Colón e incluye un puente sobre el río Chagres, aguas abajo del vertedero de Gatún.



FECHAS RELEVANTES

Inicio del diseño: 2 de junio de 2011

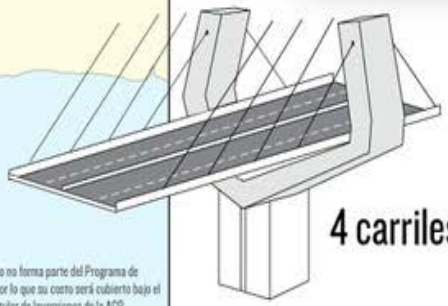
Año proyectado de terminación: 2015

Monto del contrato: **$6,496,598.53**

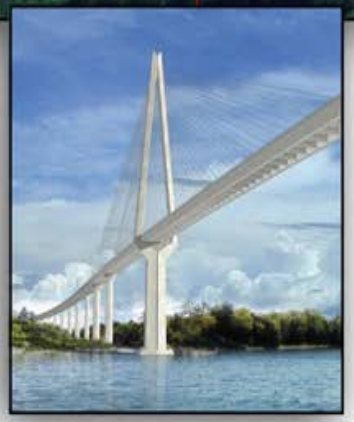
Servicios de ingeniería para el diseño final de un puente sobre el Canal en el Atlántico

Contratista: **CCCC-LBG CONSORTIUM**

*Este proyecto no forma parte del Programa de Ampliación, por lo que su costo será cubierto bajo el Programa Regular de Inversiones de la ACP.



4 carriles



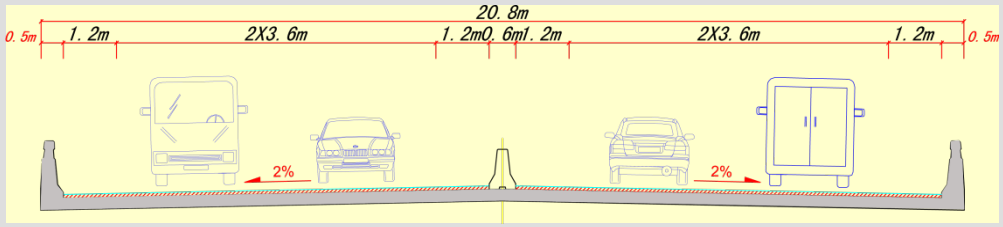
•Fuente: ACP / CCCC-LBG CONSORTIUM

Configuración General

Puente Principal	**1050m**
Viaducto Oeste	**906m**
Viaducto Este	**1125m**
Carreteras	**1400m**

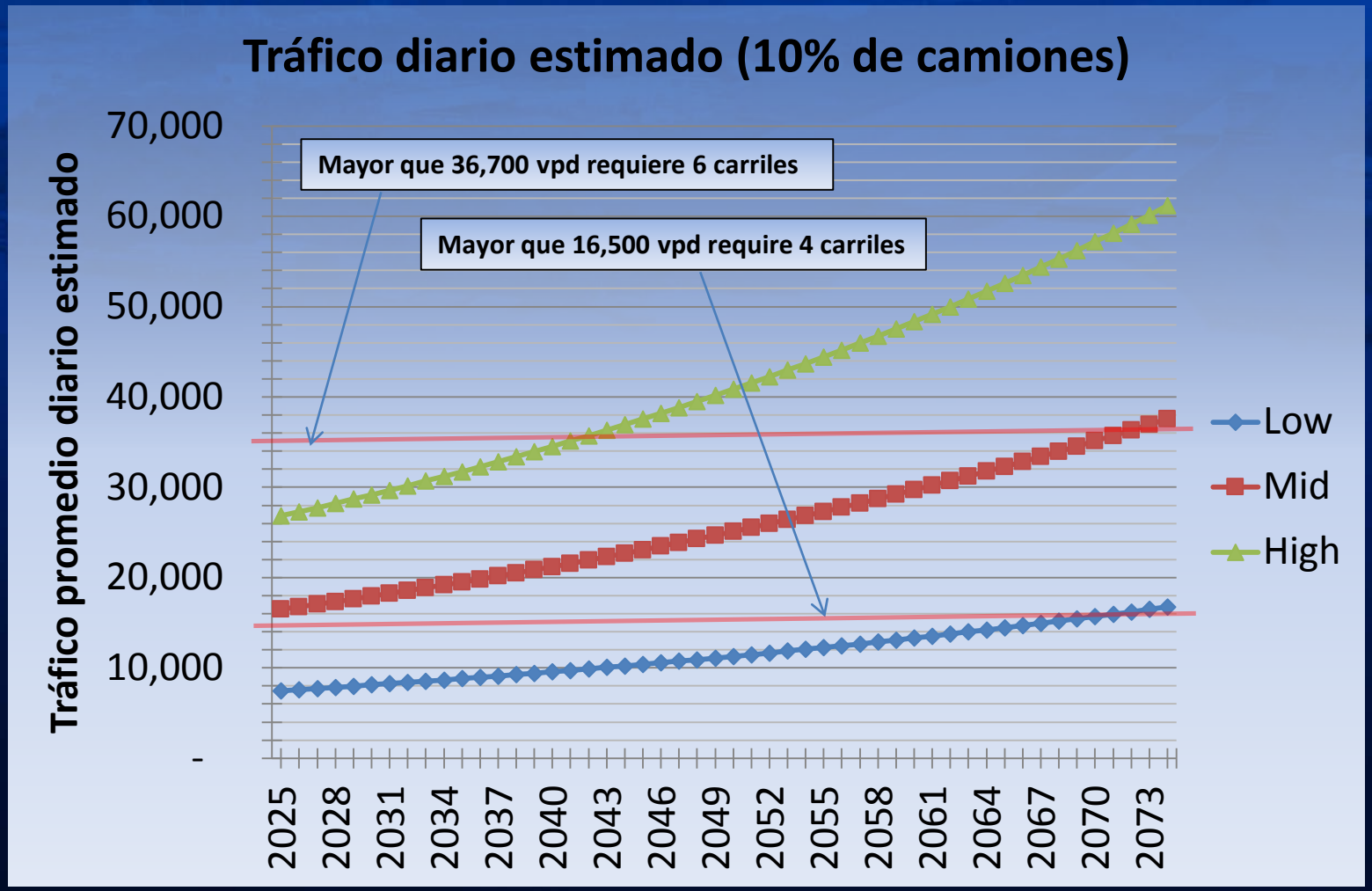
Requirimientos de Diseño

Parametros geométricos

TYPE OF MAIN BRIDGE	Concrete Cable Stayed Bridge	
TRAFFIC LANE	Dual 2-lane	
CROSS SECTION	20.8m Width	
DESIGN LIFE	. 100 yrs for Main Bridge	
DESIGN SPEED	. 90 km/h for Main Bridge	
VERTICAL CLEARANCE	75m (MHW: 0.30m PLD)	
VERTICAL GRADE	5%	

DEMANDA

DETERMINACIÓN DE NÚMERO DE CARRILES



Fuente: Autoridad del Canal de Panamá

Parámetros de Diseño

Velocidad del viento (100-year return period)

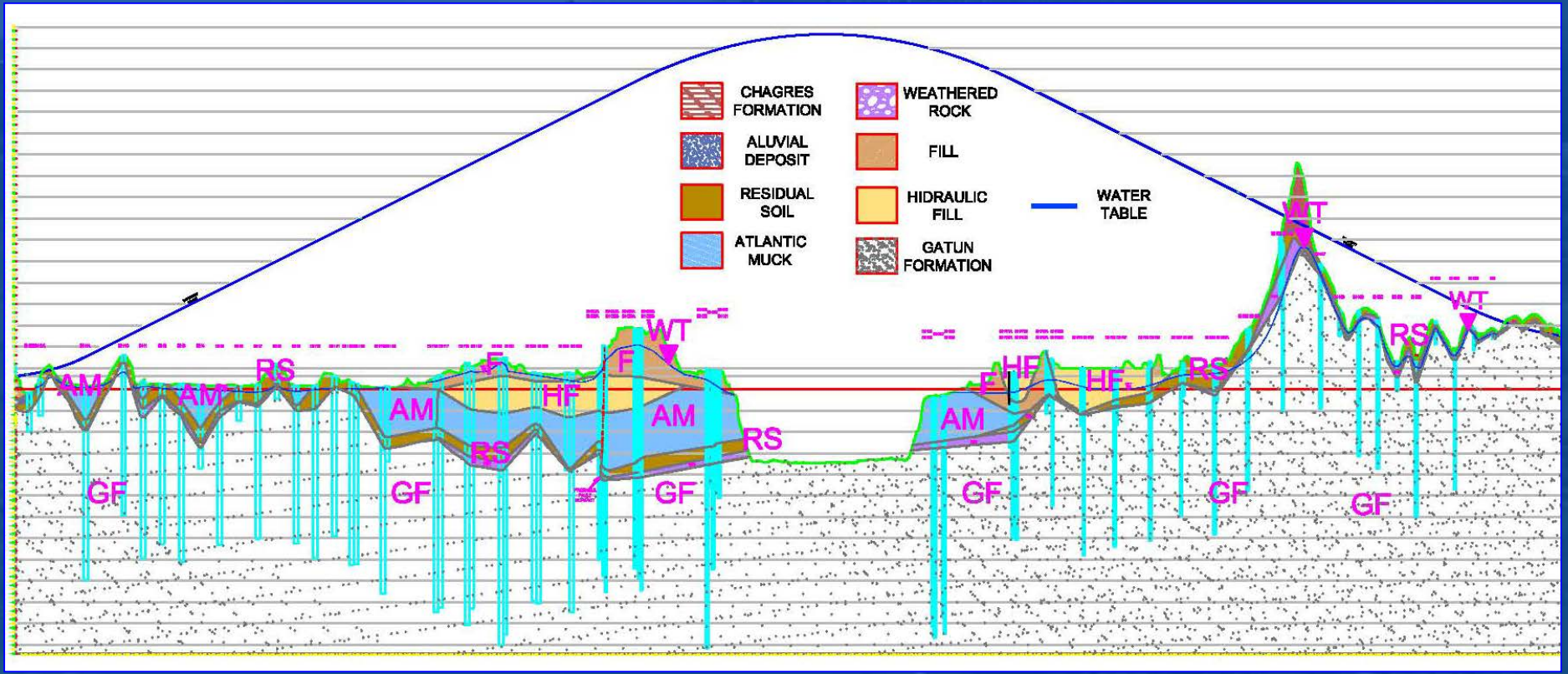
Elevation (m)	1-hr Avg. (m/s)	10-min Avg. (m/s)	3-sec Gust (m/s)
10	28.8	30.6	43.6

Analisis y Evaluación de riesgo sísmico

Seismic Hazard Level	Return Period	Events	Basic Performance Criteria
Functional Evaluation Earthquake(FEE)	475 yrs.	10% in 50yrs. Occurrence Probability	• No damage to primary structural elements • Minimal damage to other components • Full access to normal traffic immediately
Safety Evaluation Earthquake(SEE)	2,475 yrs	2% in 50yrs. Occurrence Probability	• No collapse, repairable damage • Limited access for emergency traffic in 48 h • Full service within month(s)

Design Parameters

- **Physical Characteristics — Geological**
  - AM-Atlantic Muck
  - Much higher ground PGA
  - Larger Foundation



Puente sobre el Canal en el lado Atlántico

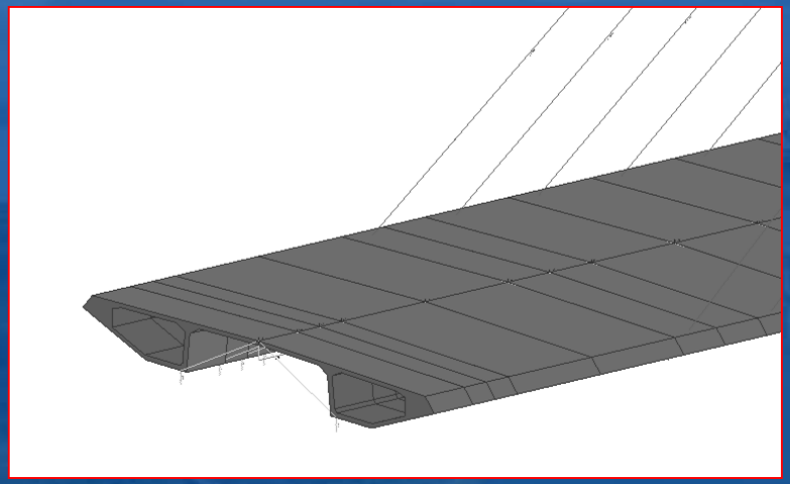
Otras consideraciones

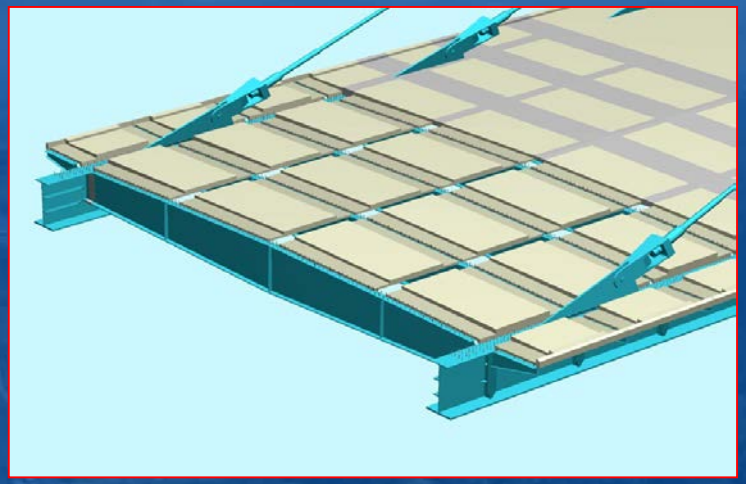
Fuente: Autoridad del Canal de Panamá

Bridge Proposals Studied

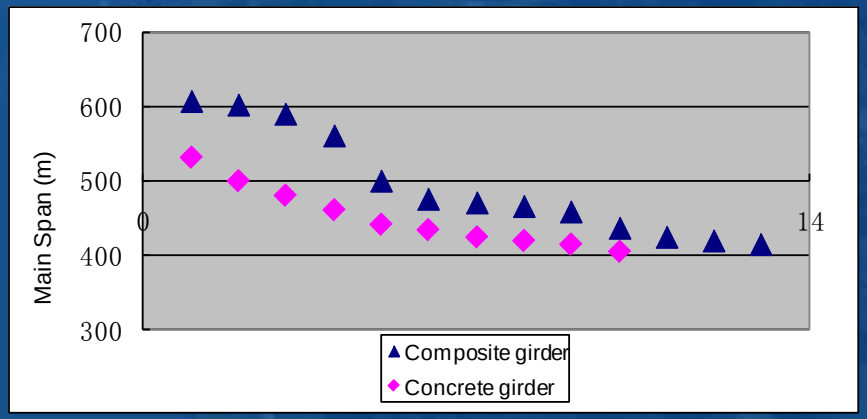
Main Bridge — Deck Structure Form

- Composite vs Concrete





- Relevant Experiences
- Overall Evaluation
- Durability
- Seismic Behavior
- Costs
- Potential Risks



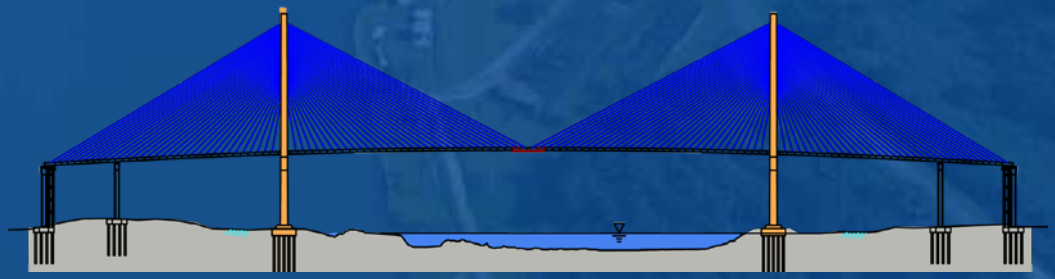
Erección del Puente no debe interrumpir el tráfico de buques en el cauce

Solución Técnica

- **Puente Principal — Erección de la Cubierta**

1

2



3

Bridge Proposal Studied

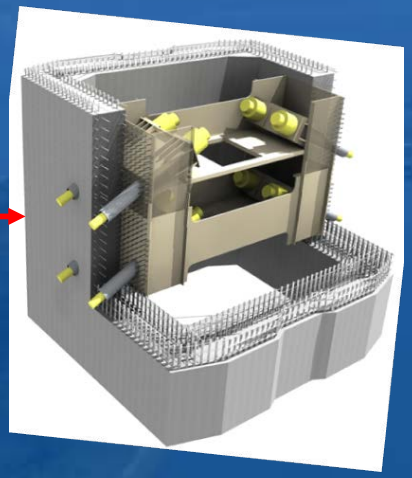
- **Main Bridge** — Deck Structure Form

  - Concrete Deck

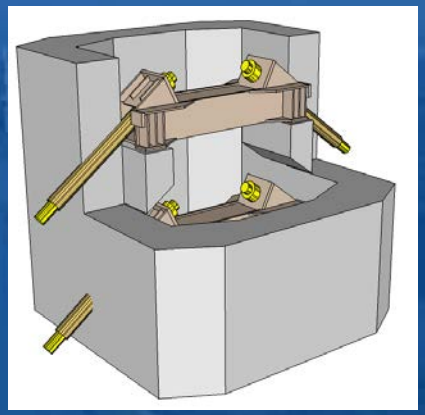
Option / ITEM	Option 1	Option 2	Option 3
Aeroelastic Stability	**Poor**	**Good**	**Best**
Structural Rationality	**Fair**	**Better**	**Better**
Segment WT.(8m)	**378 T**	**326T**	**332T**
Erection	**Simple Formwork**	**Moderate**	**Complex**
Conclusion	X	**Recommended**	X

Bridge Proposals

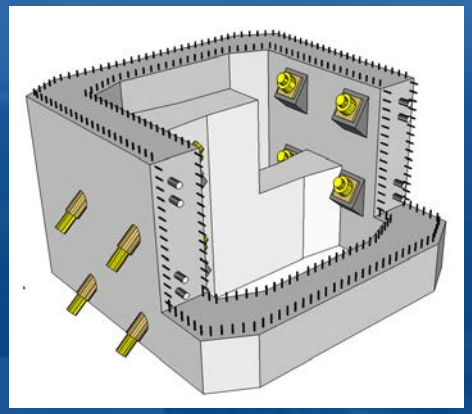
- **Main Bridge** — **Anchorage Type**



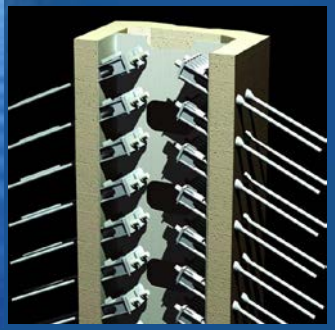
Option 1
Steel Anchor Box



Option 2
Steel Anchor Beam

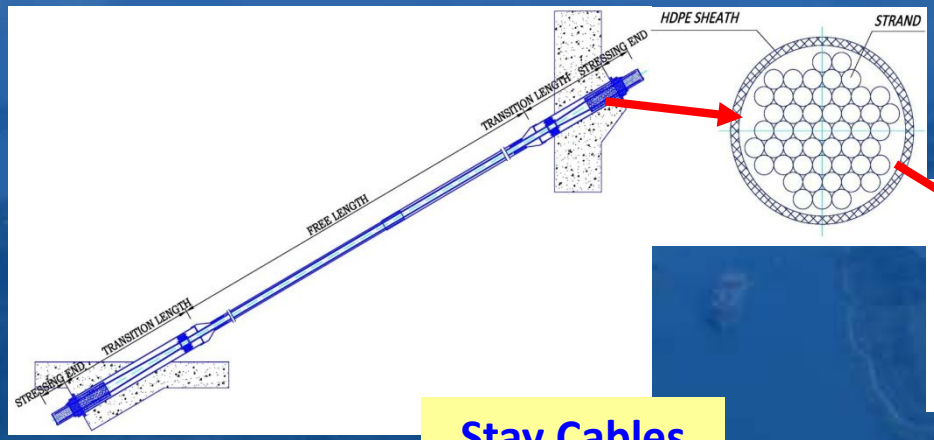


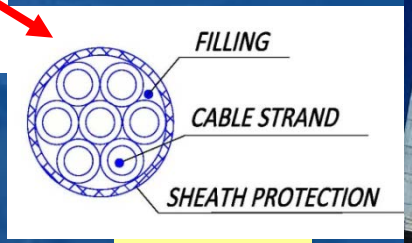
Option 3
PT Bar
(Design)



Technical Solution

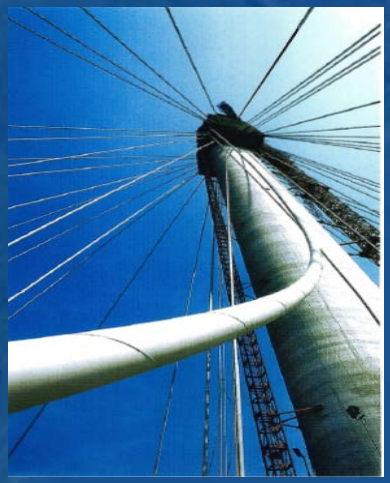
- **Main Bridge** — **Cable System**
  - **256 Stay Cables**

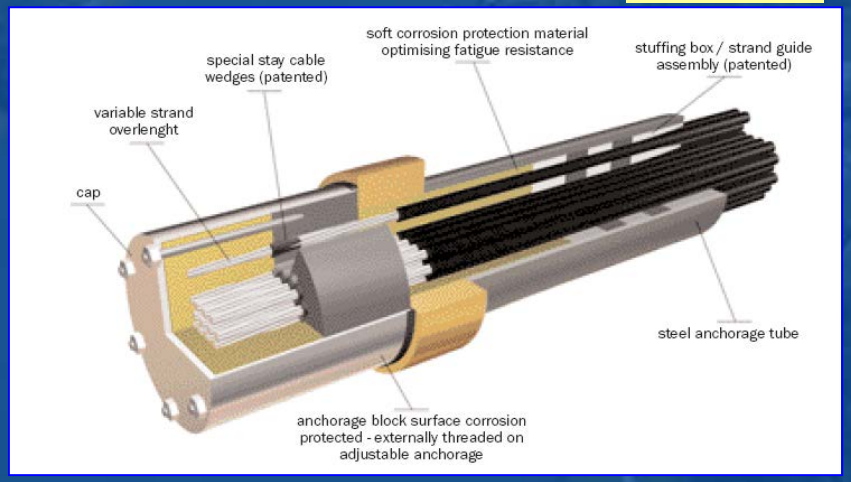


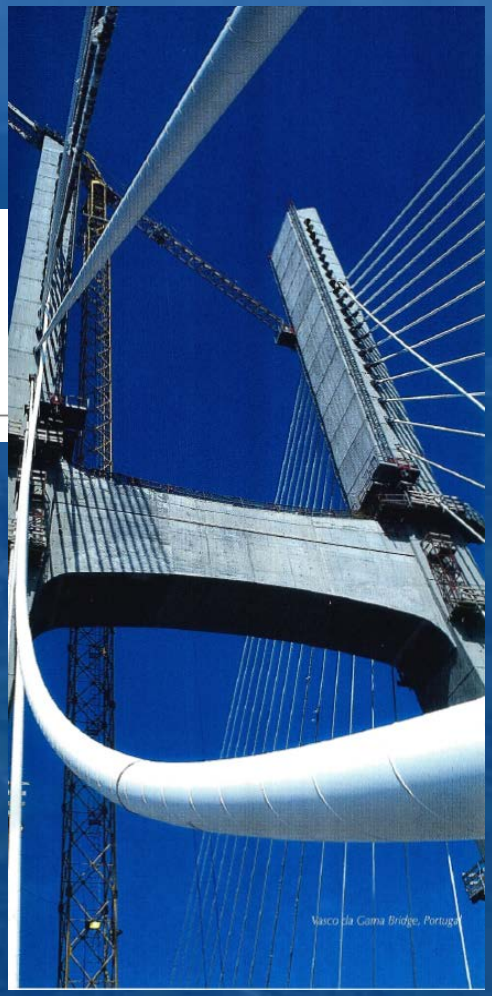


Stay Cables

Strand

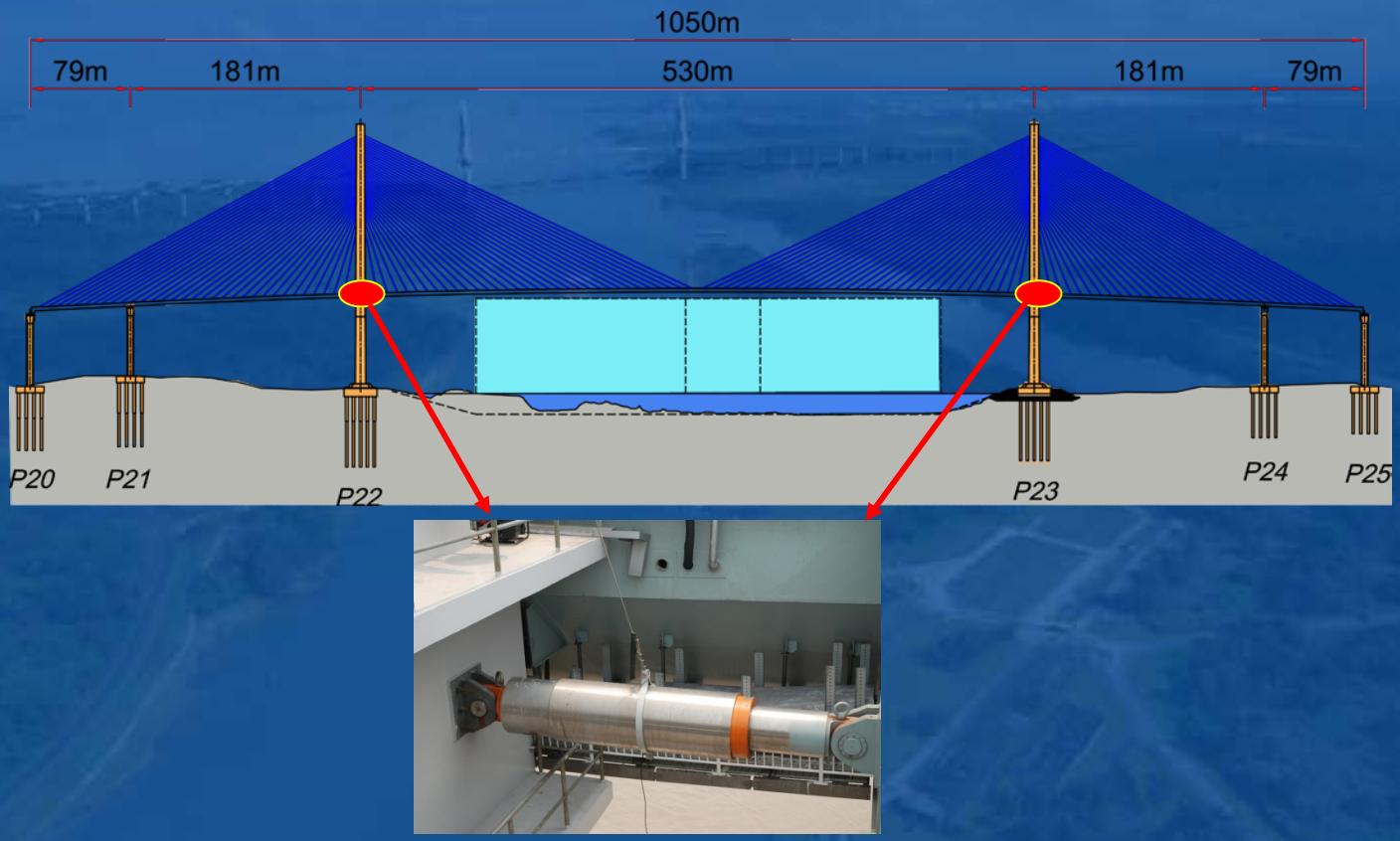






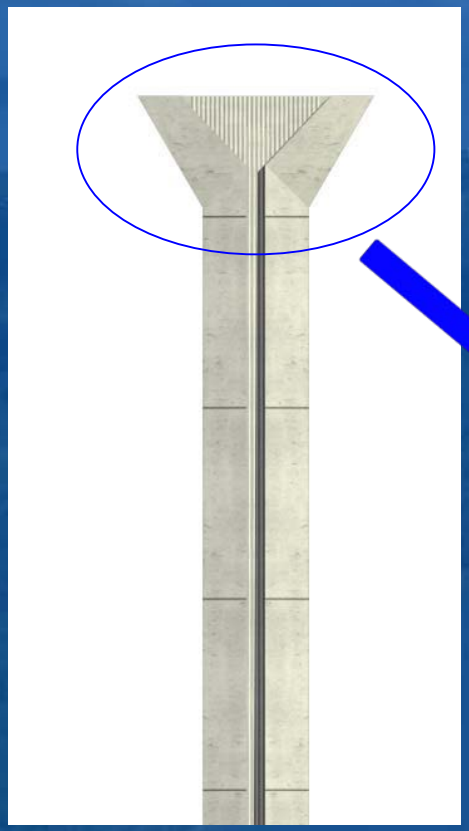
Special Studies Performed

- Seismic Hazard Assessment & Seismic Analysis
  - Solution: Viscous Damper



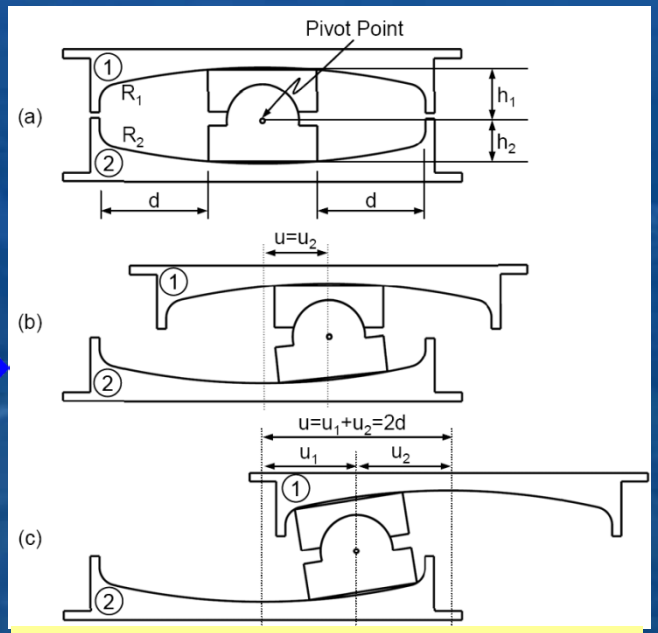
Special Studies Performed

- Seismic Hazard Assessment & Seismic Analysis
  - Solution: Double Concave Friction Pendulum Bearings



Viaduct Piers

DCFP Bearings



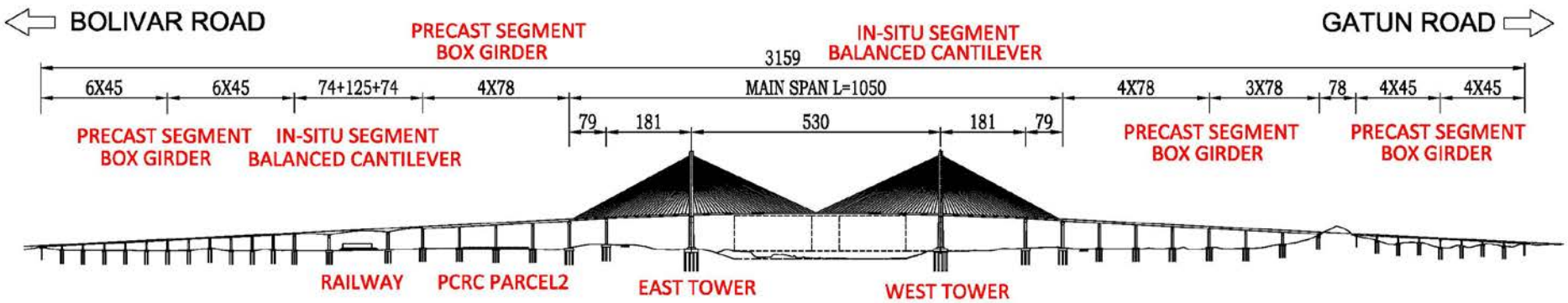
DCFP Bearings at Various Stages of Movement

Technical Solución Técnica

- Configuración General
- Puente principal
- Viaducto de aproximación

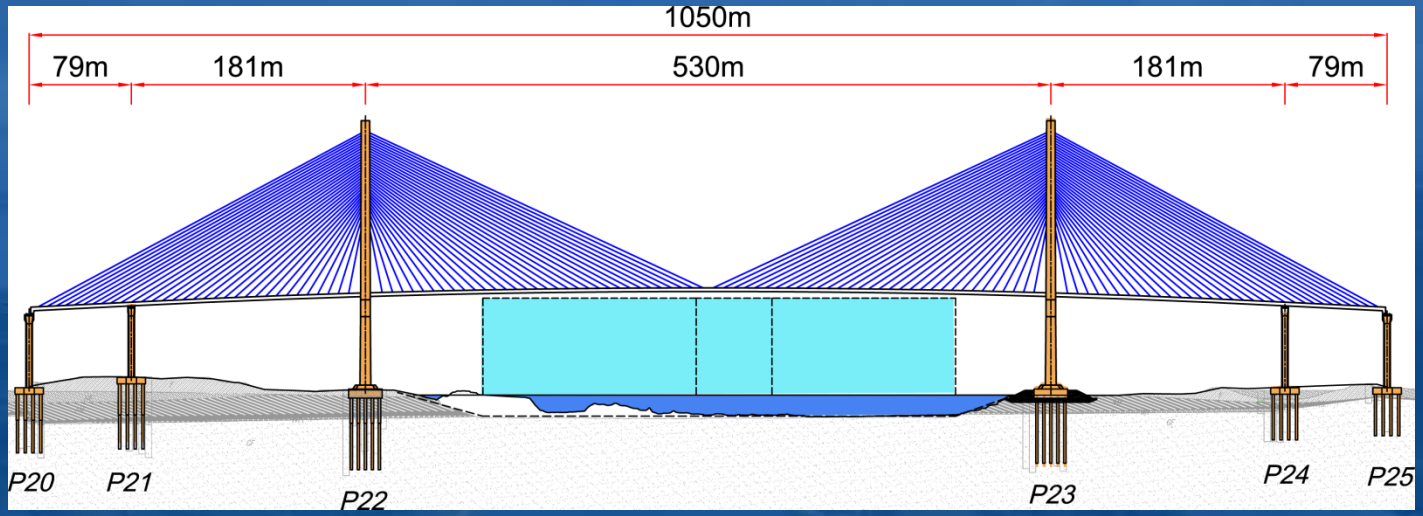
Technical Solution

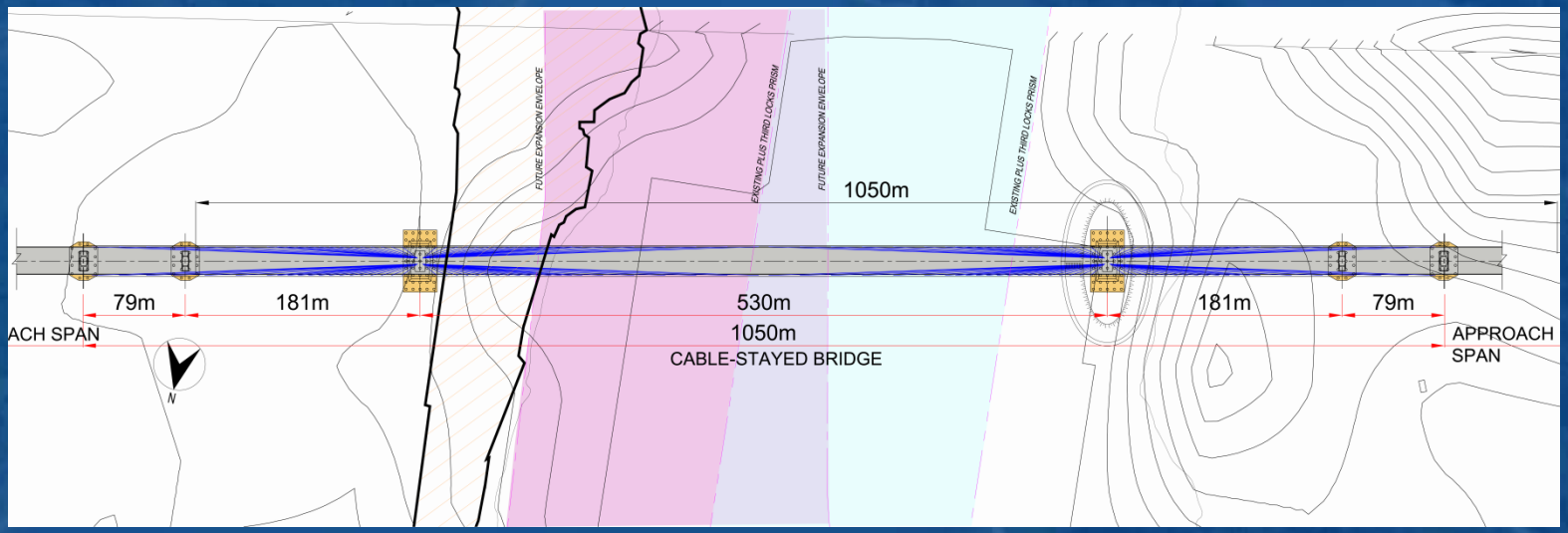
General layout



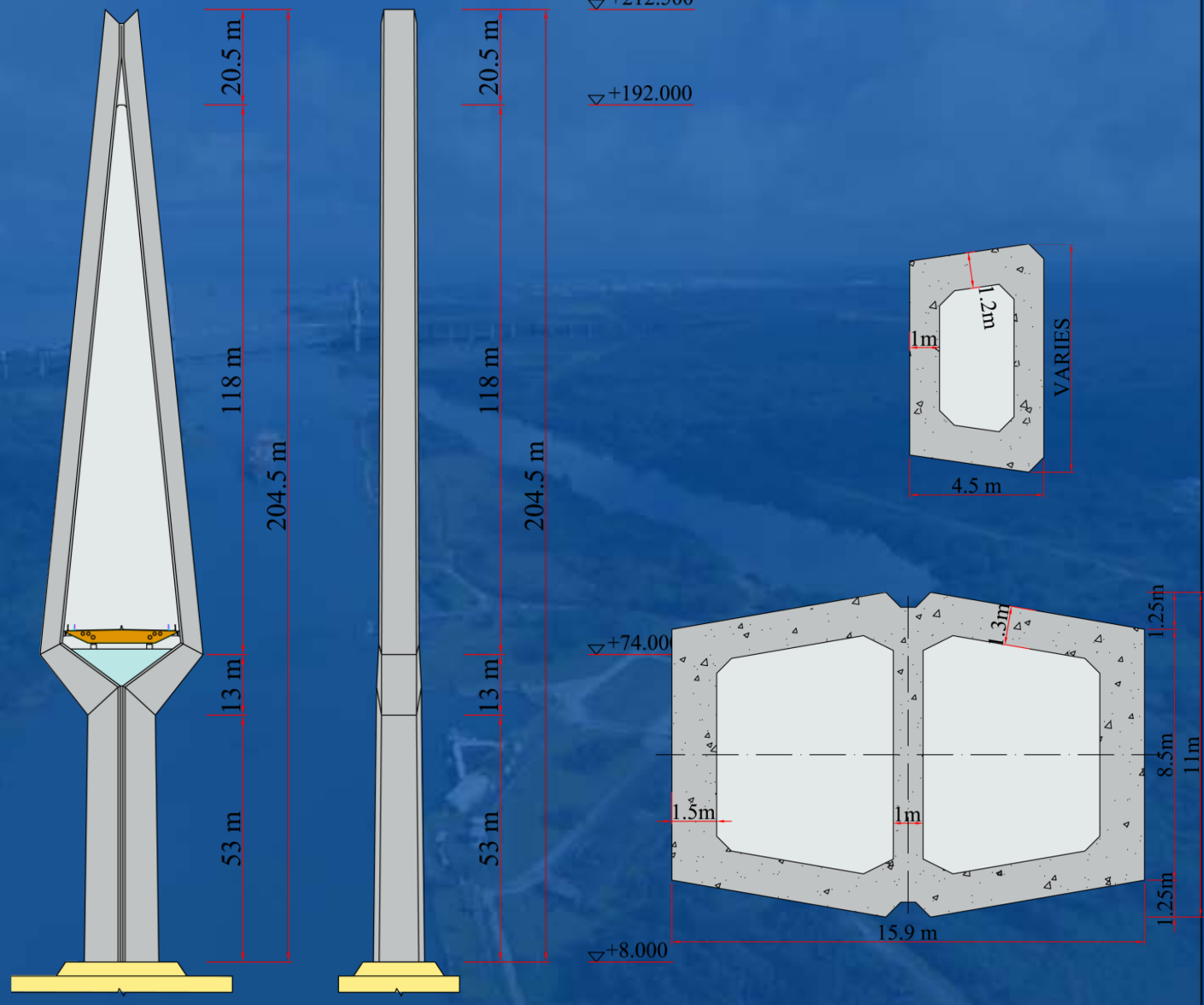
Technical Solution

Main Bridge — Span Arrangement





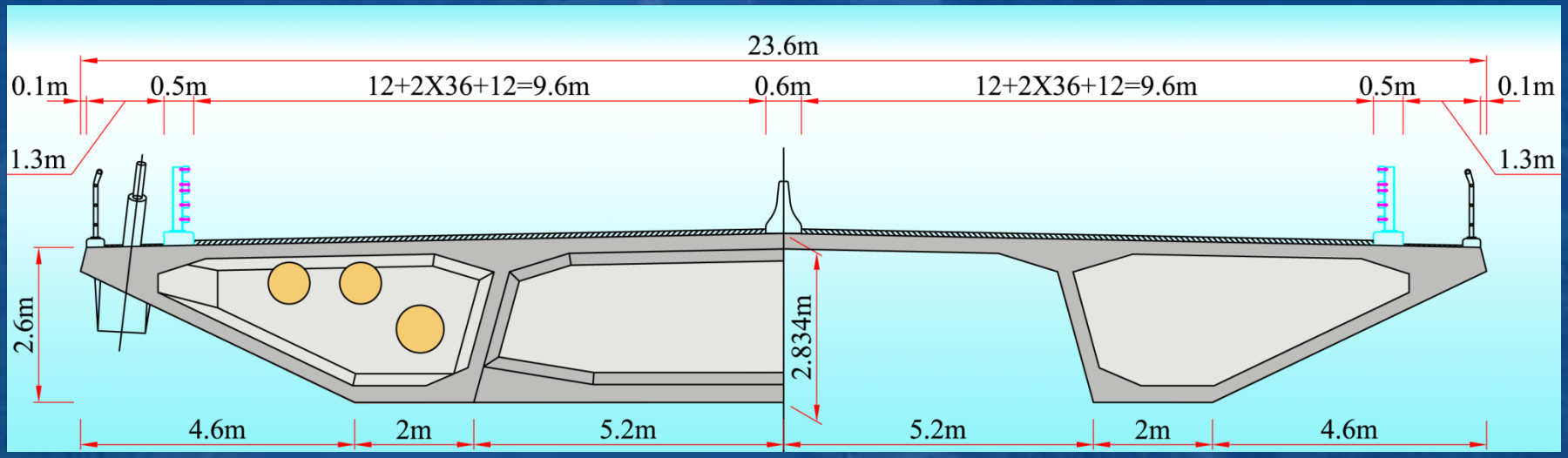
Puente Principal — Torre



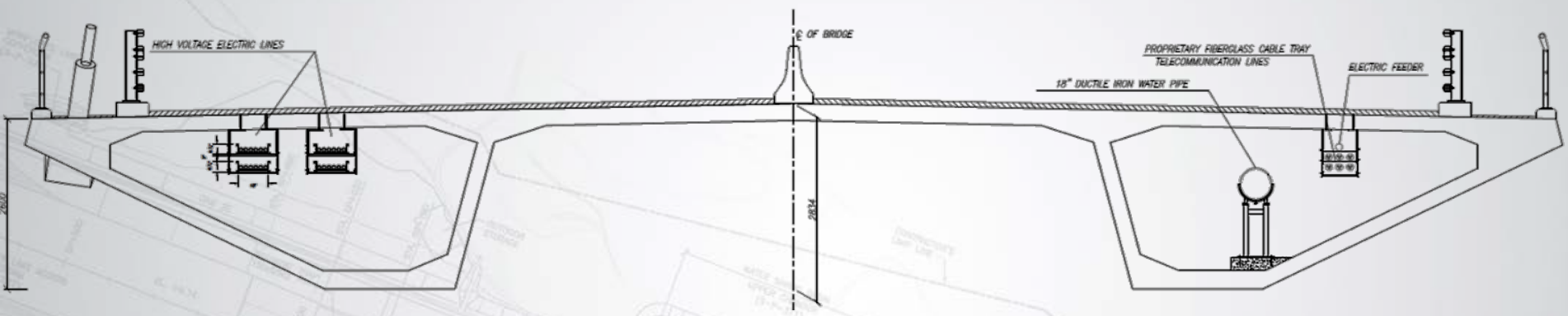
Technical Solution

Main Bridge — Deck Cross Section

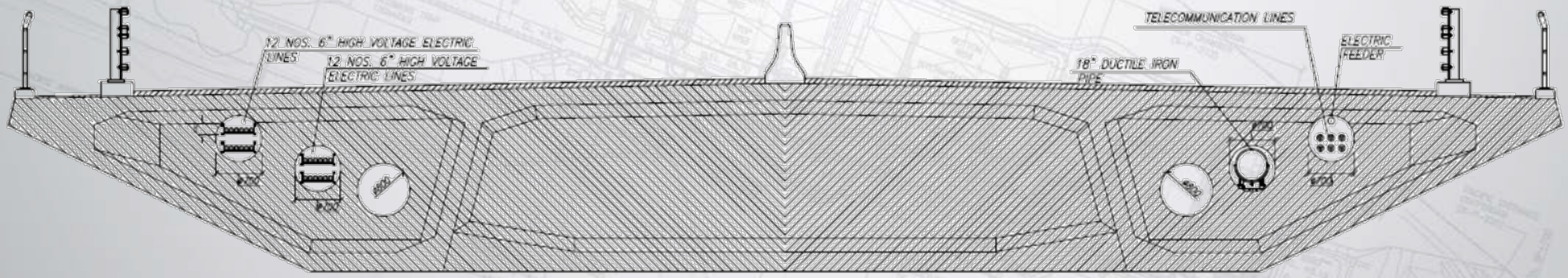
- 8m Segments in Main Span
- 7m & 8m Segments in Side Span
- Typical Segment Wt: 300T



Technical Solution

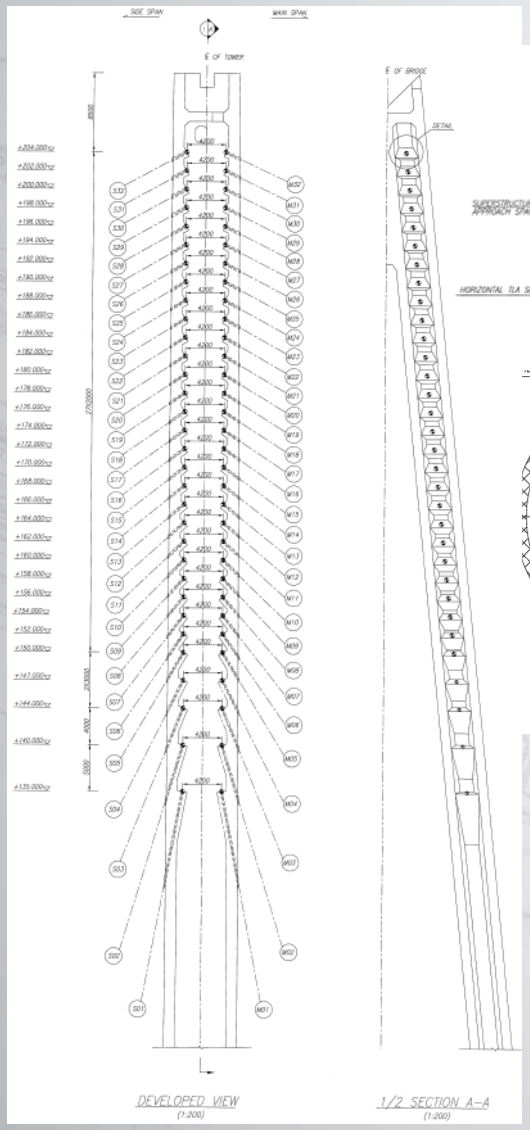


Typical Cross Section

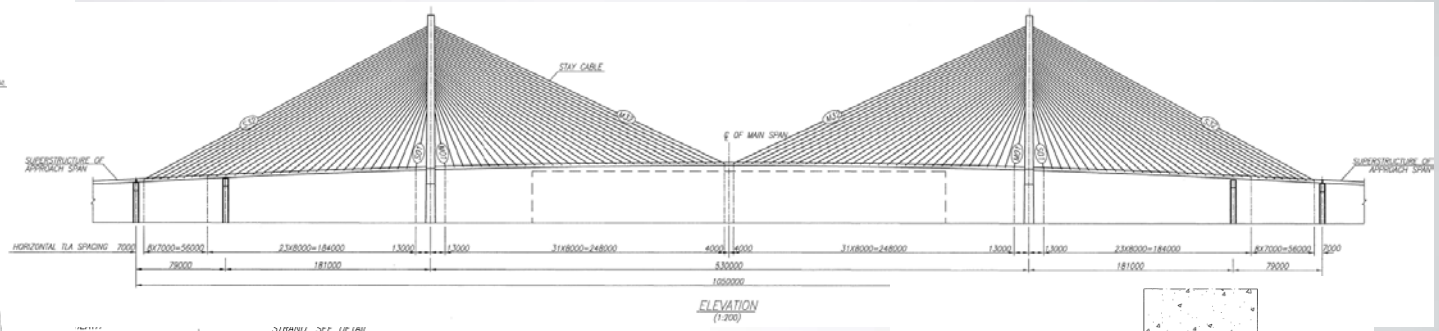


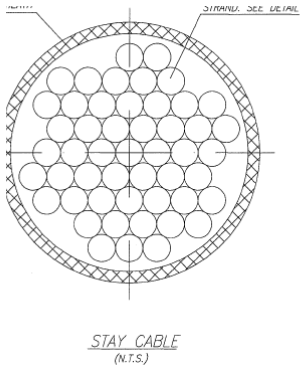
Typical Cross Section (Diaphragm)

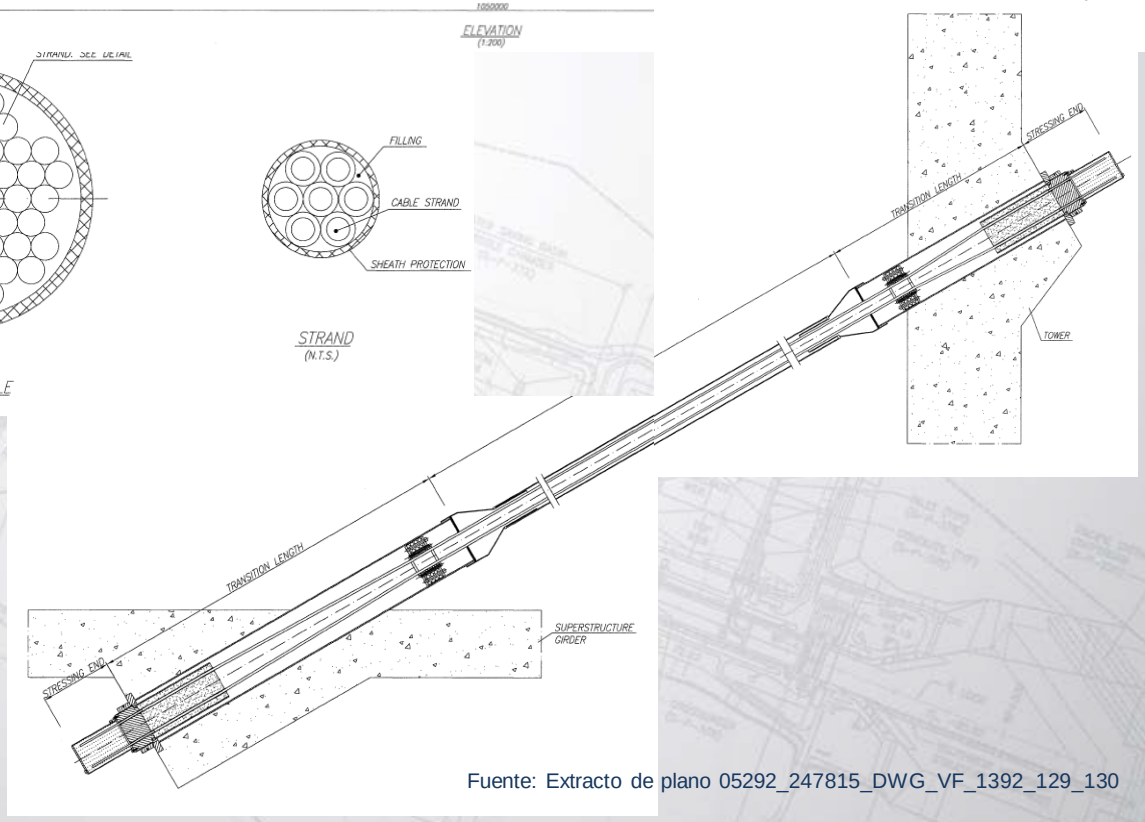
Aspectos Técnicos



Fuente: Extracto de plano 05292_247815_DWG_VF_1392_129_27





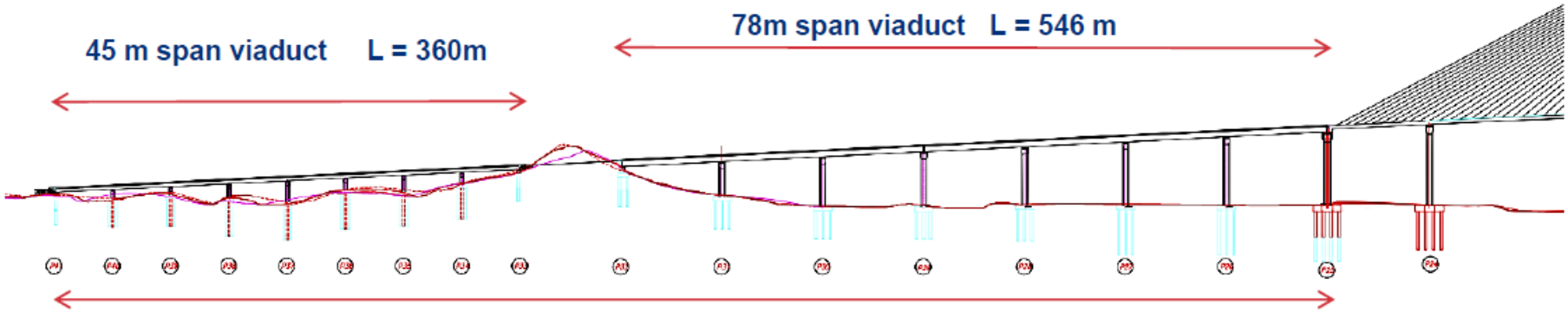


Fuente: Extracto de plano 05292_247815_DWG_VF_1392_129_130

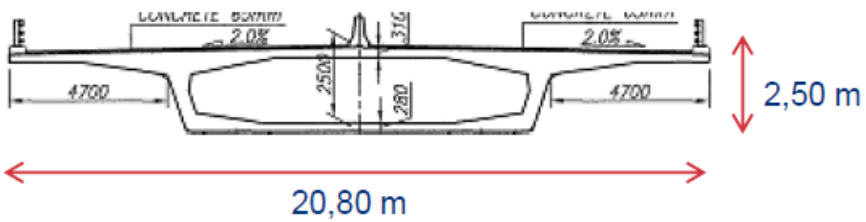
Technical Solution

- Approach Viaduct

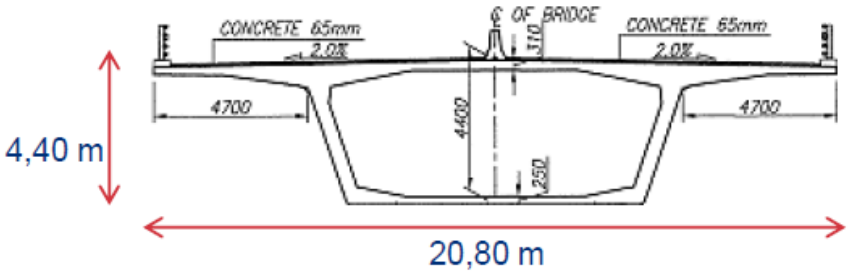
Viaductos de acceso del Oeste



L = 984m
Western Access Viaduct

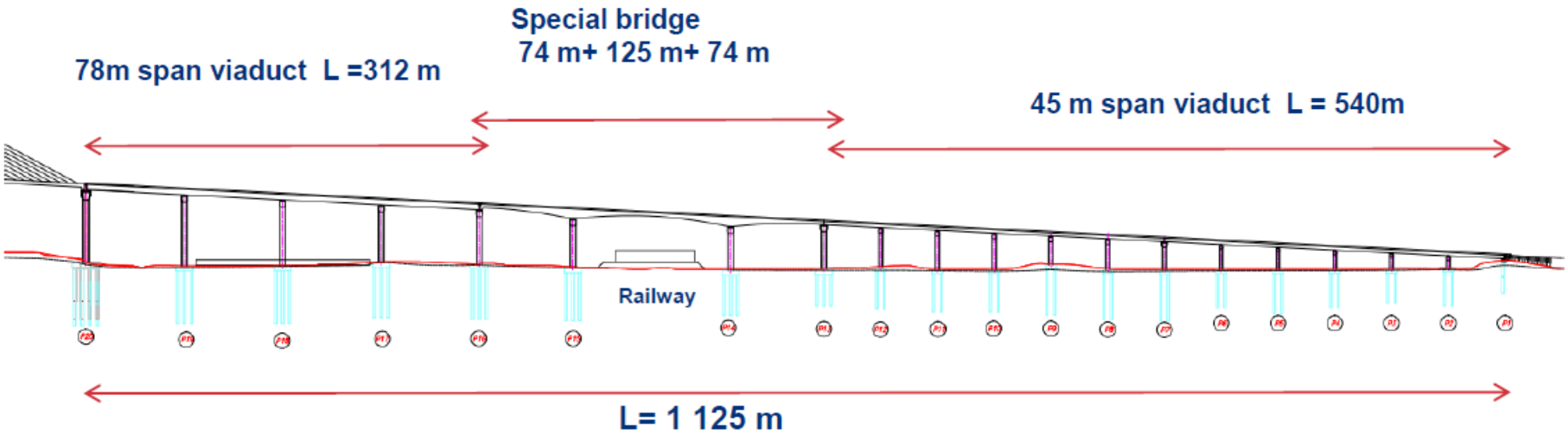


45 m span deck



78 m span deck

Viaductos de acceso del Este



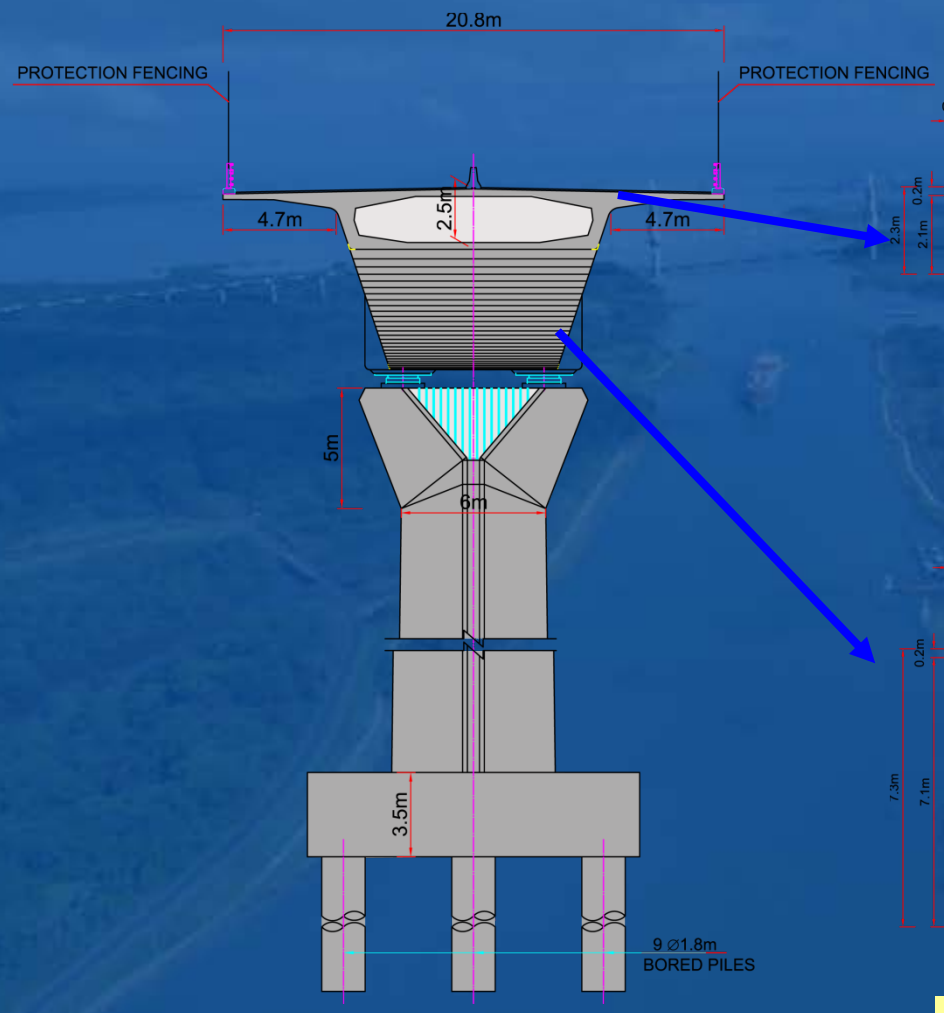
Eastern Access Viaduct

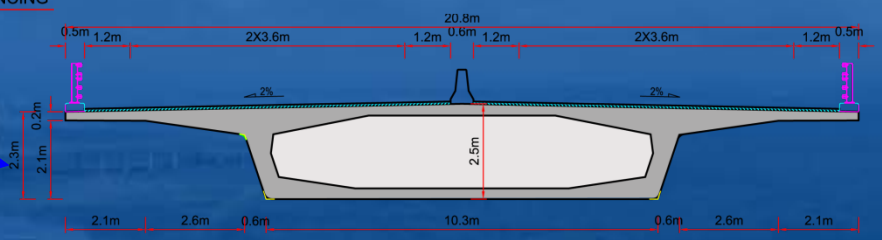
Construction methods for the access viaducts :

- 45 m span viaduct : launched box girder
- 78 m span viaduct : cast in place cantilever construction
- Special bridge : cast in place cantilever construction

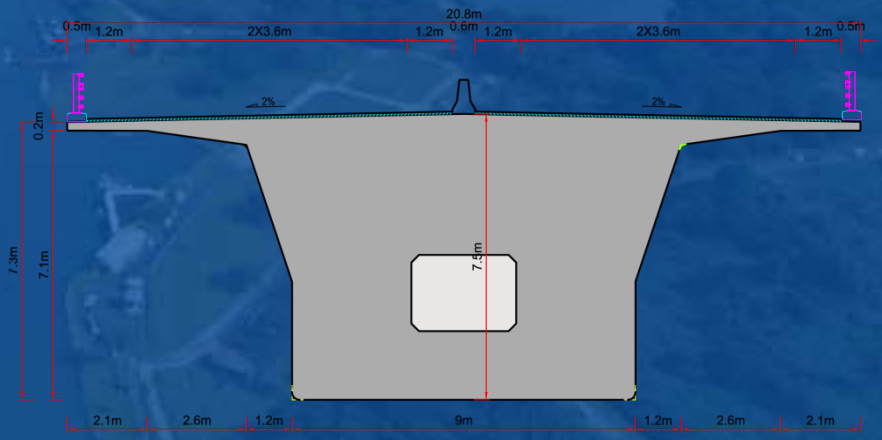
Technical Solution

Approach Viaduct — 74+125+74m Approach Viaduct





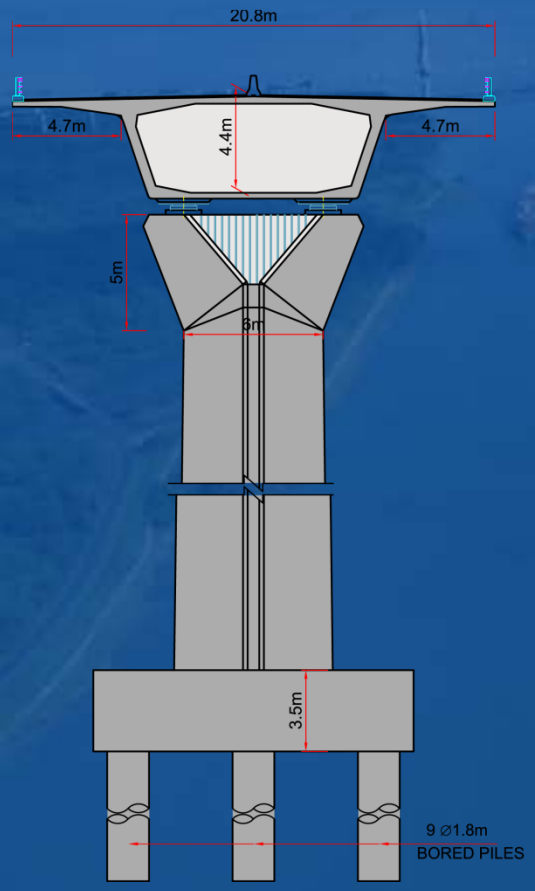
Typical Cross Section of Midspan

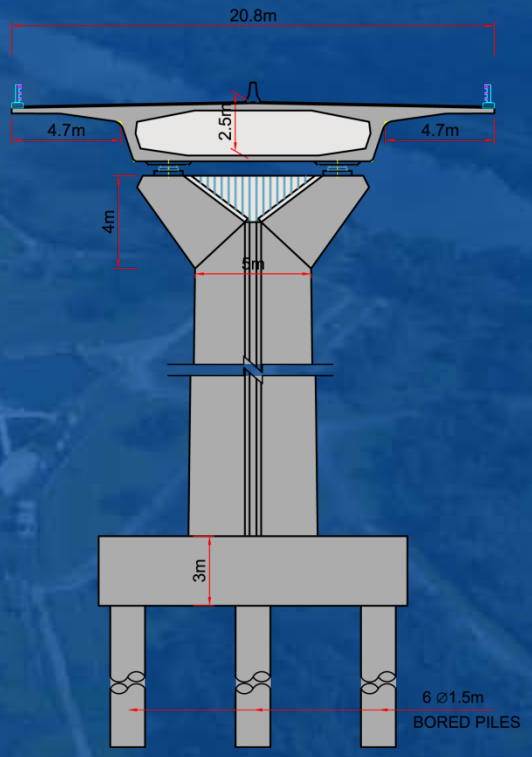


Typical Cross Section of Piers Location

Technical Solution

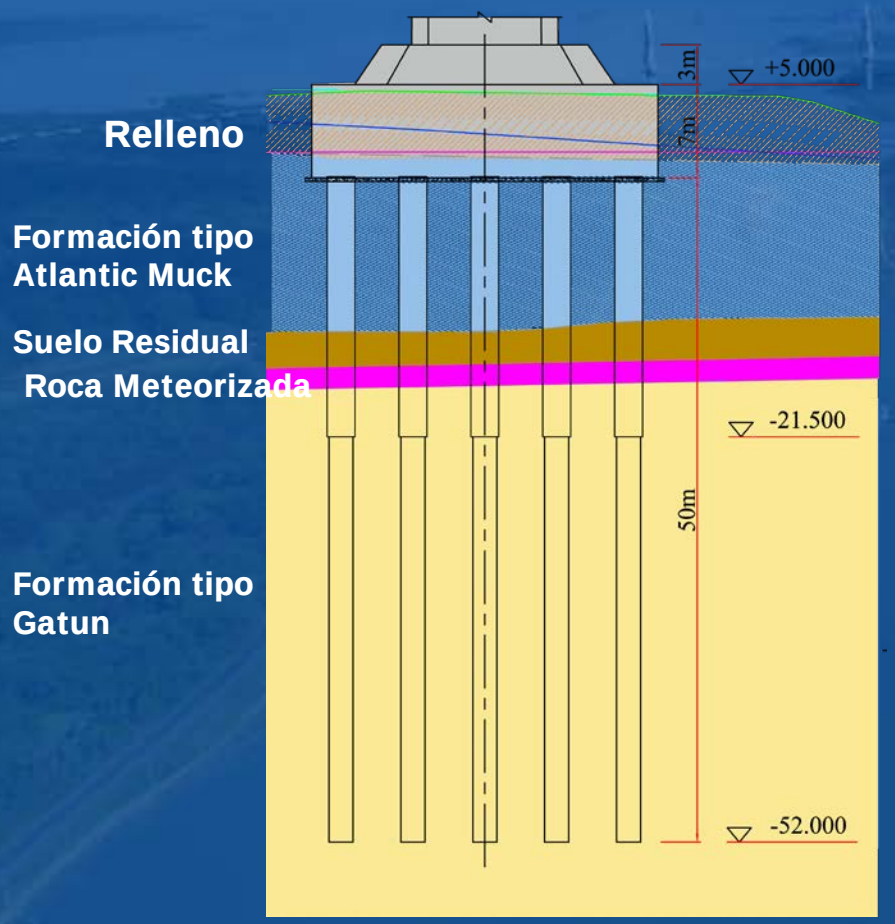
- **Approach Viaduct — 78m & 45m Approach Viaduct**
  - **78m Viaduct:** 4.4m Depth of Girder, 9 D1.8m Bored Piles
  - **45m Viaduct:** 2.5m Depth of Girder, 5 or 6 D1.8m Bored Piles

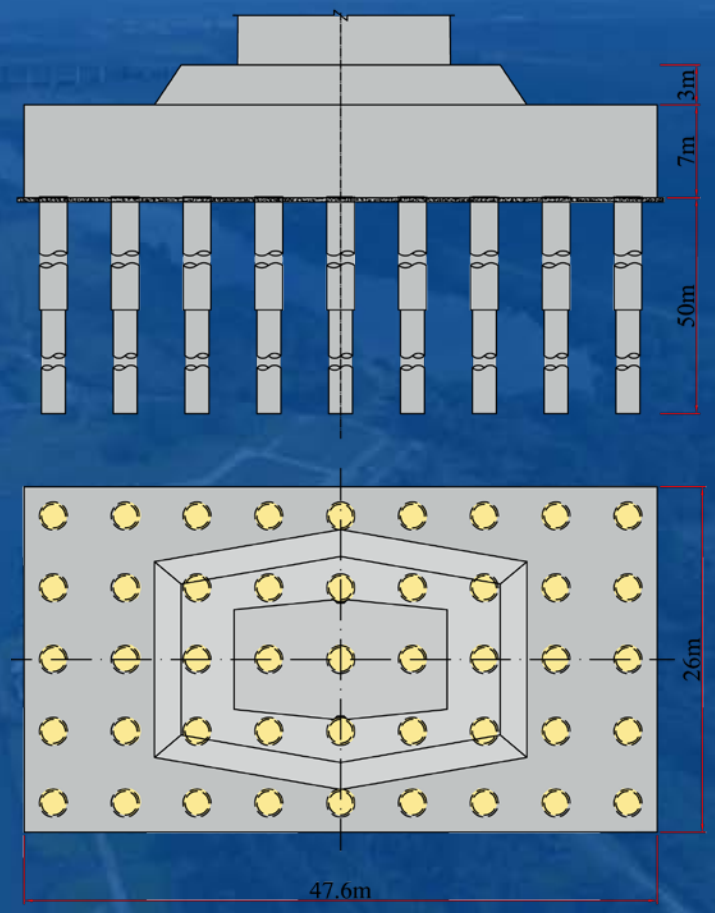




Puente Principal — Fundación de la Torre

- Este: 35 D 2.5m
- Oeste: 45 D 1.8m





Puente sobre el Canal en el lado Atlántico

Otros estudios y verificaciones

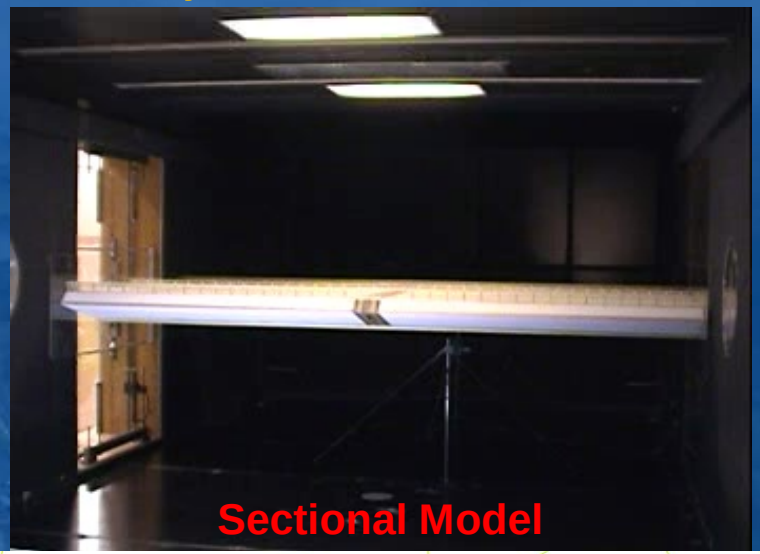
Fuente: Autoridad del Canal de Panamá

Special Studies Performed

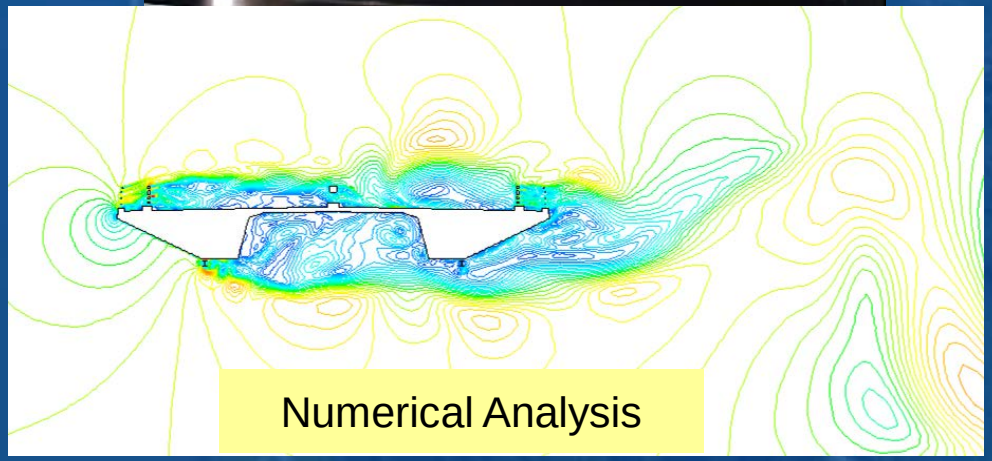
Wind Tunnel Tests & Aerodynamic Stability

- The Bridge Posses Enough Aeroelastic Stability

Smooth &Turbulence flow



Sectional Model



Numerical Analysis

Special Studies Performed

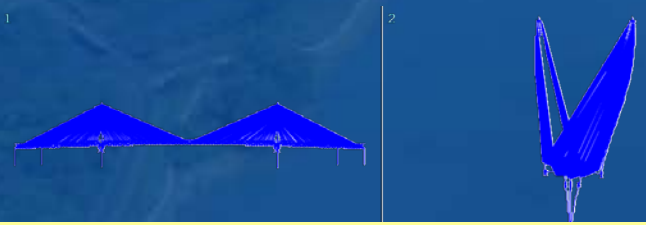
Wind Tunnel Tests & Aerodynamic Stability

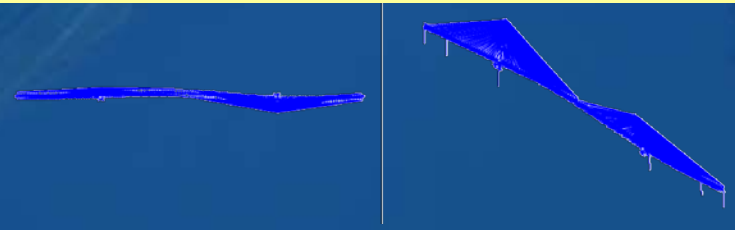
Sectional Model of the Service State

Sectional Model of the Construction State

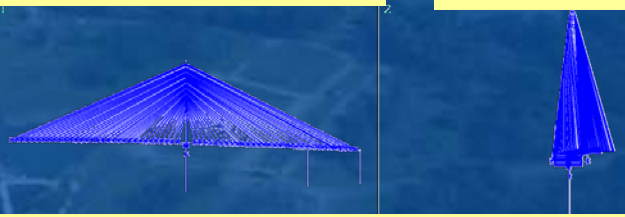
Smooth flow

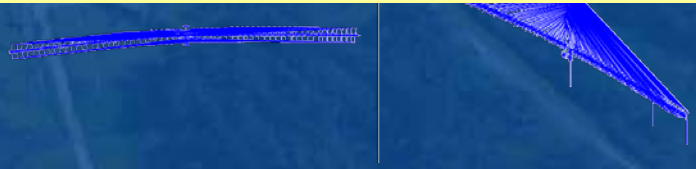
Turbulence flow





Aerodynamic Analysis of the Service State



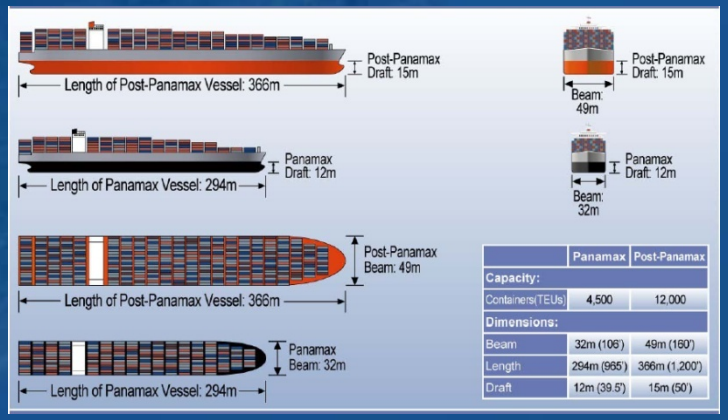


Aerodynamic Analysis of the Construction State

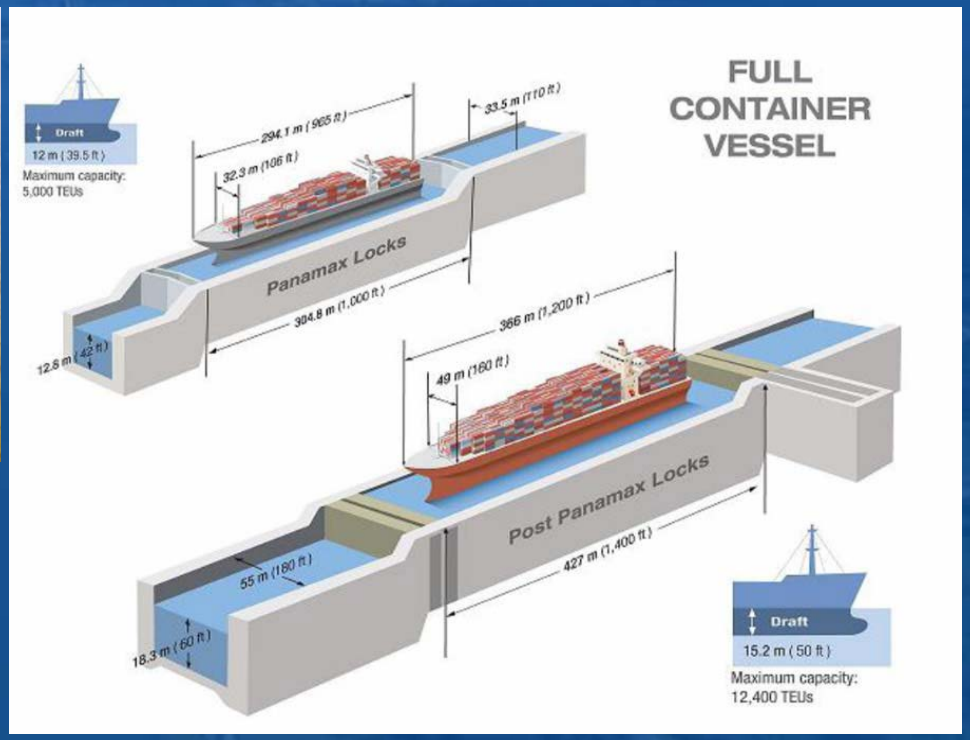
Special Studies Performed

Vessel Grounding Study

- 12,400TEU Container Vessel with Laden Draft 15m, Displacement 165,000t Ballast Draft 8m, Displacement 90,000t



	Panamax	Post-Panamax
Capacity:		
Containers(TEUs)	4,500	12,000
Dimensions:		
Beam	32m (106')	49m (160')
Length	294m (965')	366m (1,200')
Draft	12m (39.5')	15m (50')

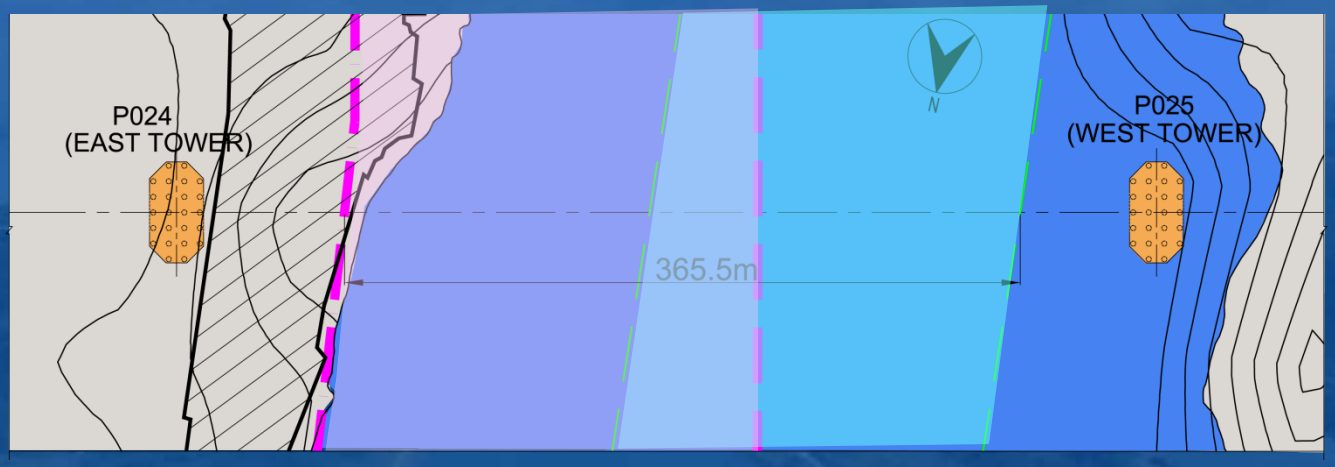


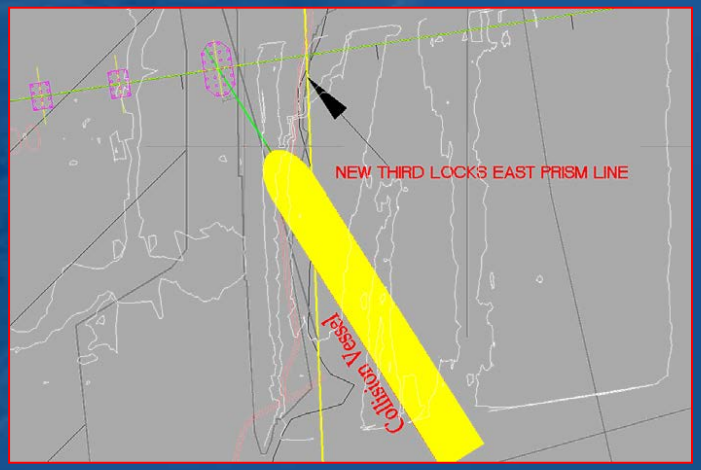
The Grounding Speed: 8 knot, i.e. 4.11m/s

Special Studies Performed

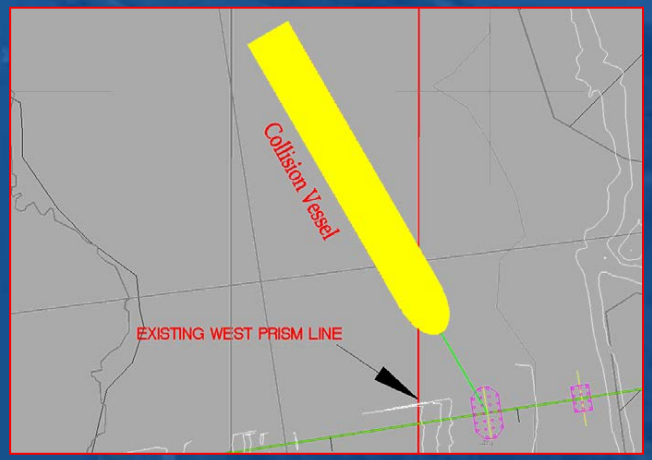
Vessel Grounding Study

- Collision Angle: 30°



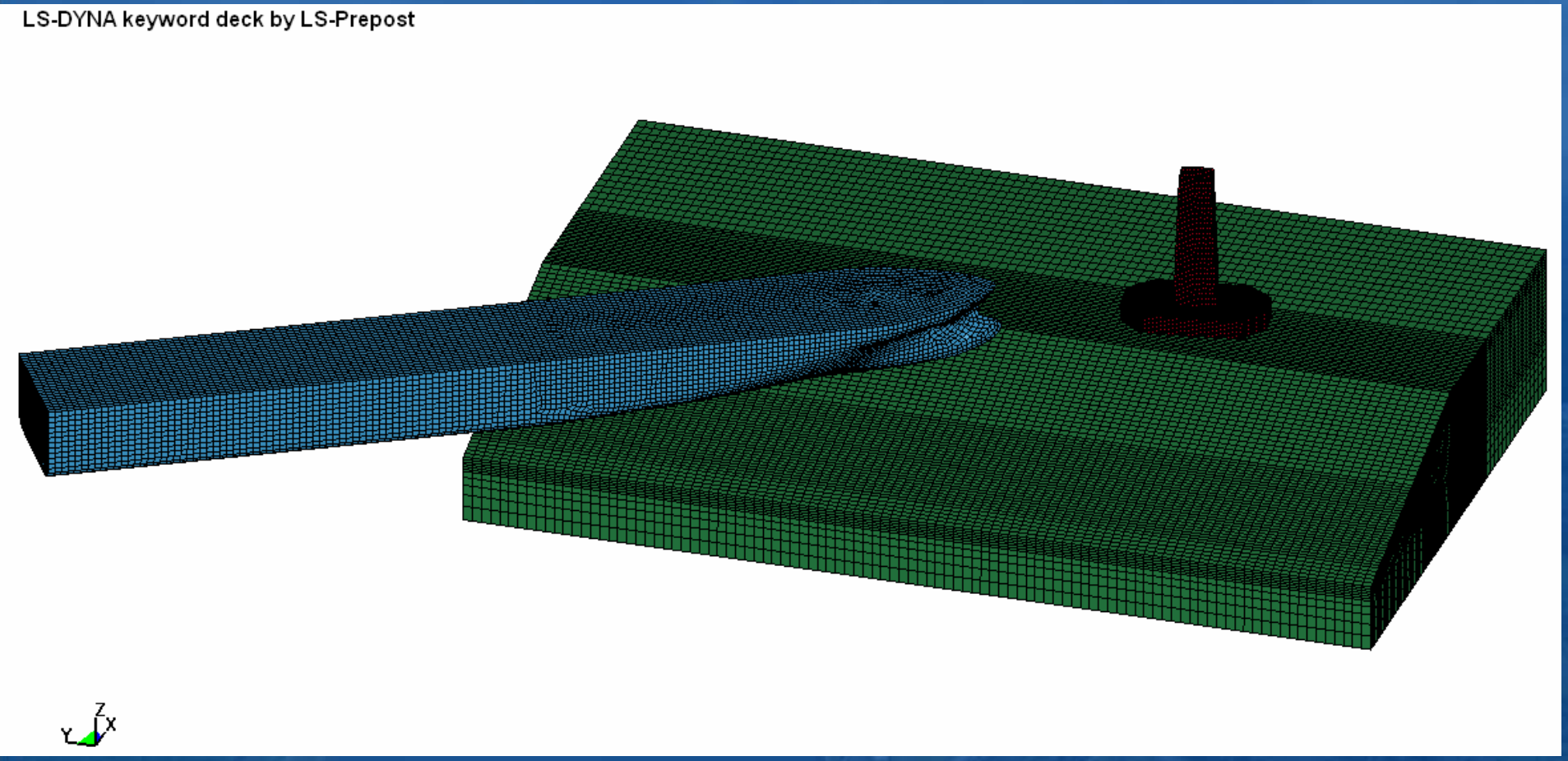


East Tower



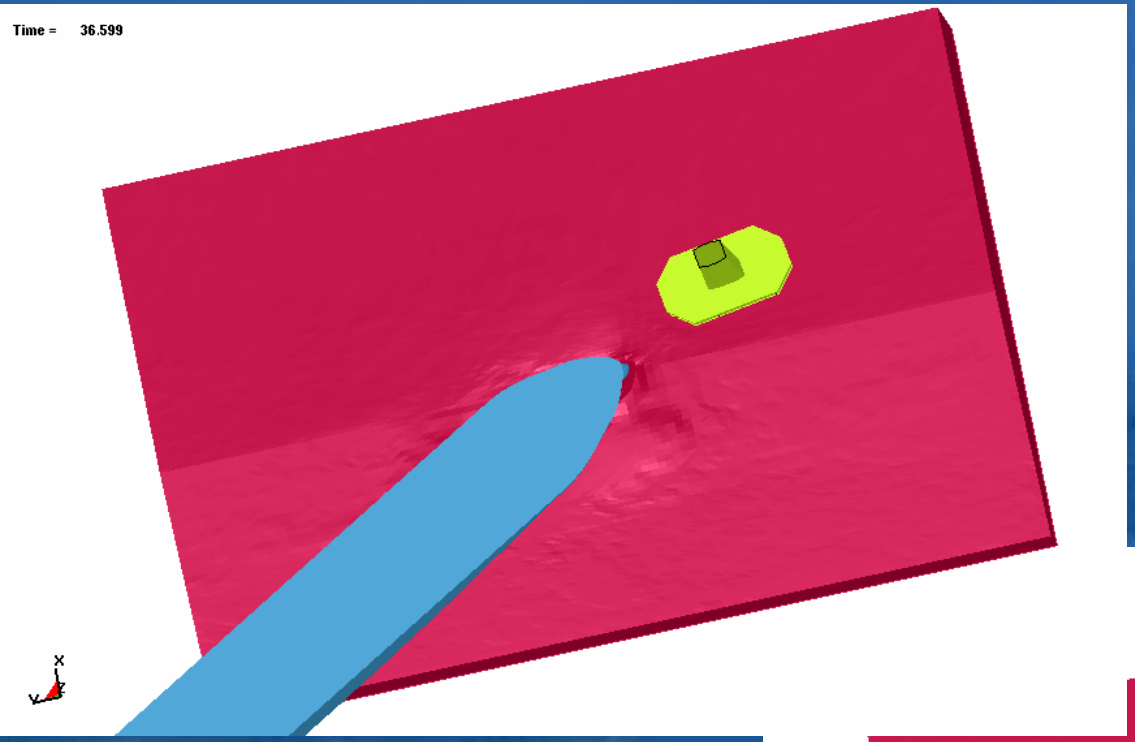
West Tower

Special Studies Performed



MEF spatial view

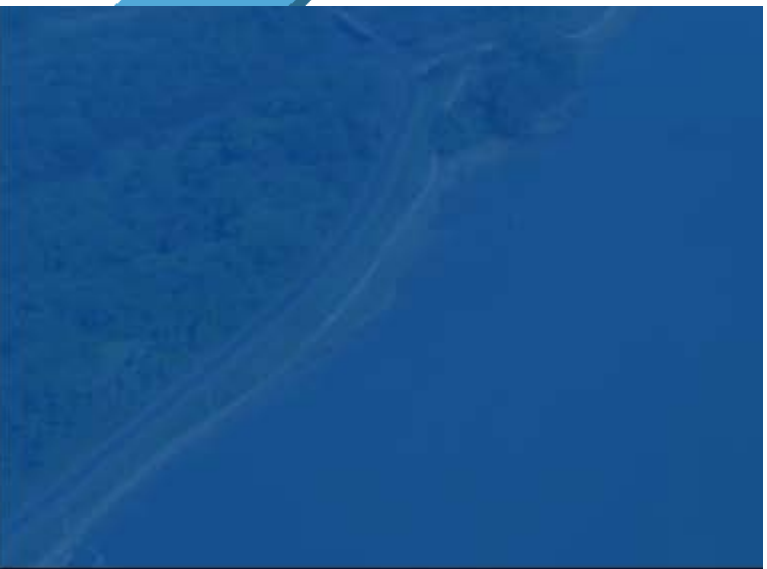
Special Studies Performed

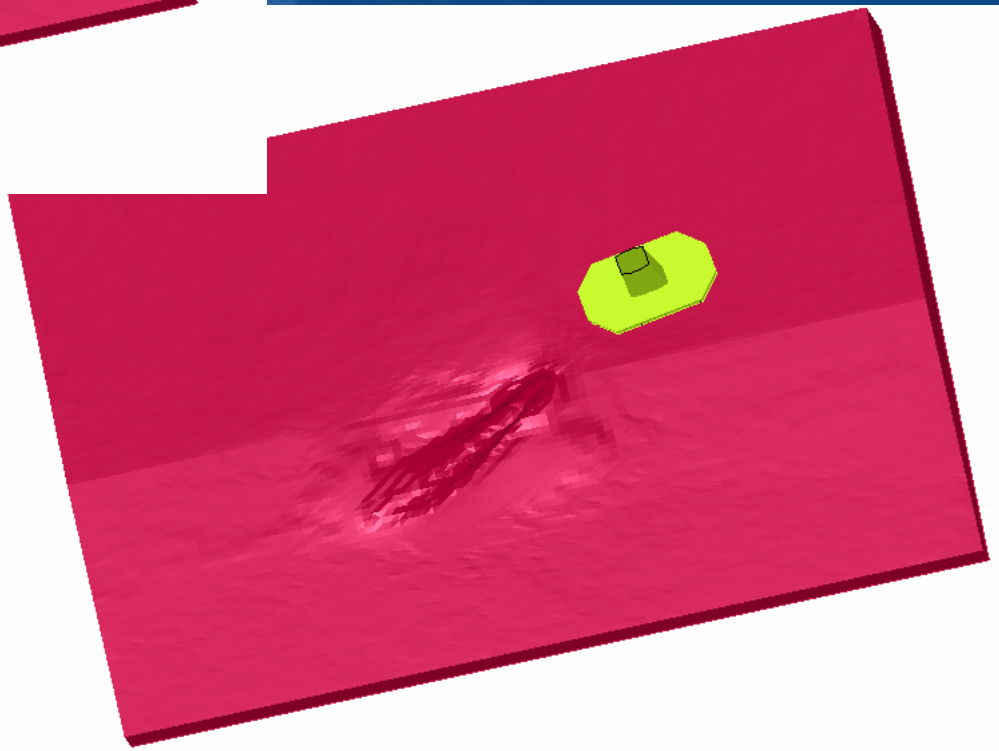


West Tower

Ladden vessel

draft 15m



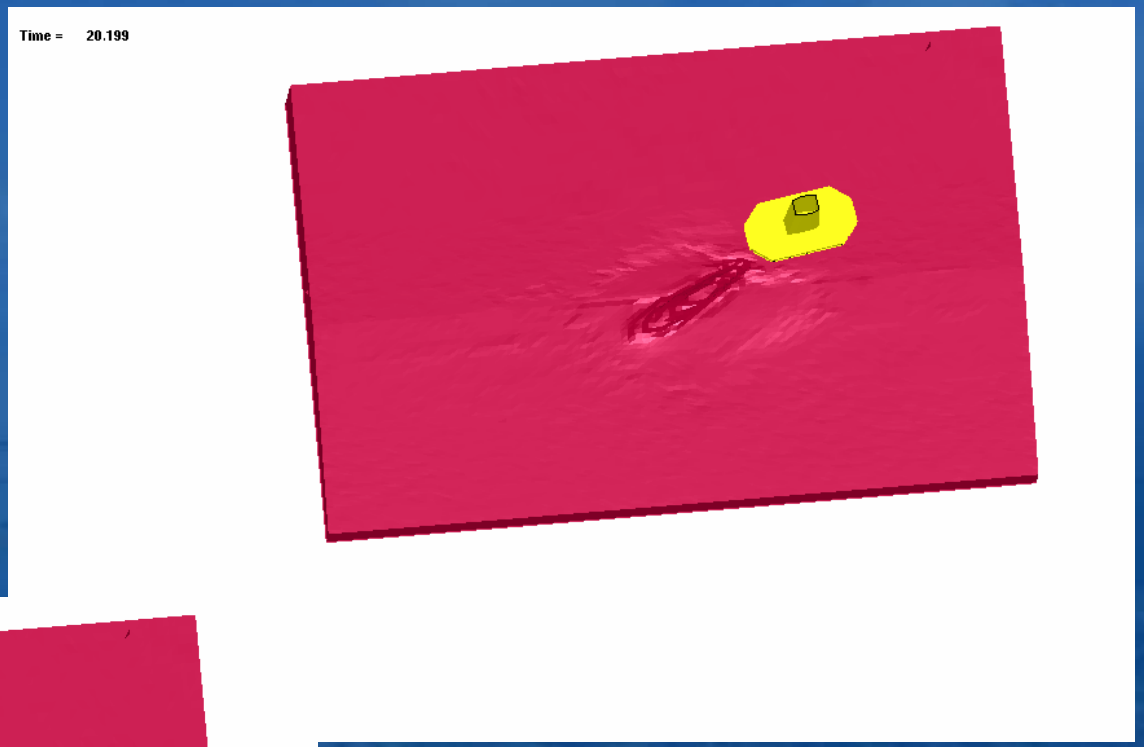


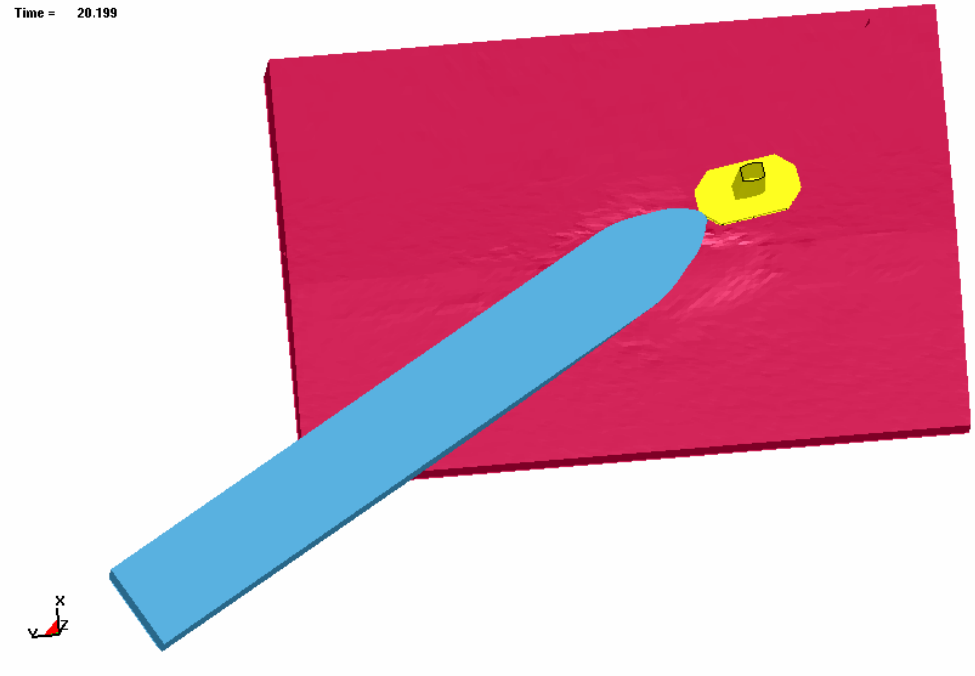
Special Studies Performed

West Tower

Ballast vessel

Draft 8m

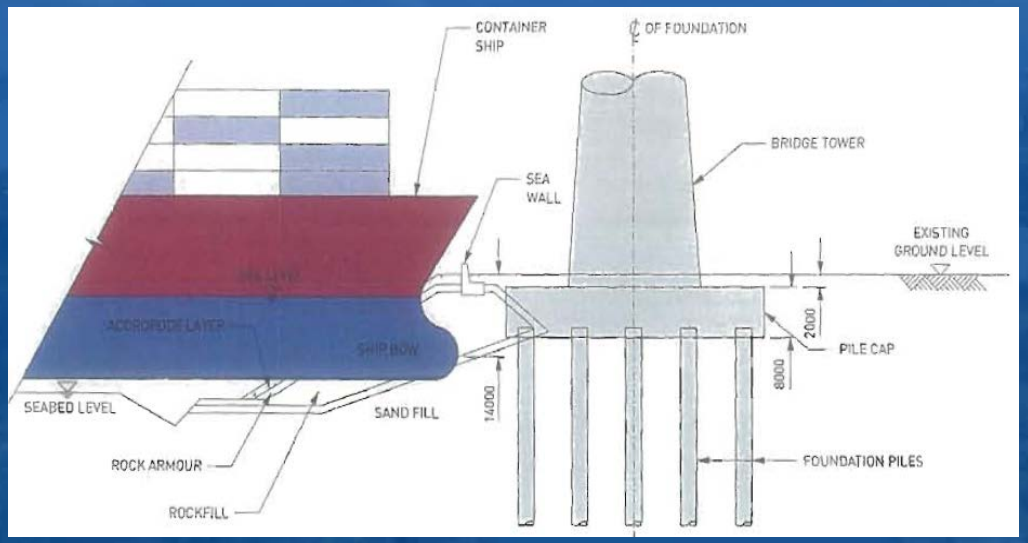


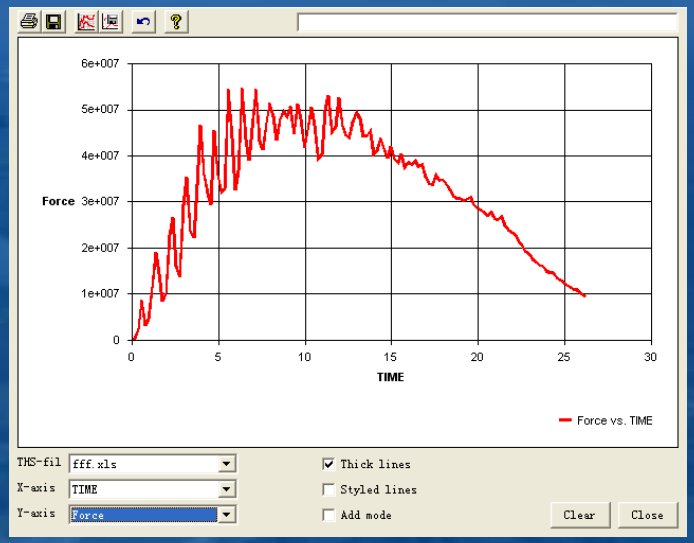


Special Studies Performed

Vessel Grounding Study

- Finite Element Methods Analysis





		Max. Sliding Dist. /Resistance	Max. Soil Pressure (kPa)	Min. Dist. to the Footing (m)	Footing Horiz. Force (MN)	Pile Group Max.Horiz. (MN)
East Tower	Full laden	28.1m/92MN	290	16.5	4	8
	Empty	27.8m/40MN	310	8.6	9	12
West Tower	Full laden	56.0m/60MN	355	16.0	5	9
	Empty	52.3m/53MN	367	0	55	

Special Studies Performed

- **Vessel Grounding Study**

For East Pylon: The errant vessel at the design condition will not impact and contact the east main pier directly.

For West Pylon: The errant vessel in ballast condition will impact and touch the piles-cap with the speed of 1.5m/s after grounding energy consumption. In this case, the foundation is still safe with reasonable margin.

Puente sobre el Canal en el lado Atlántico

Metodos Constructivos

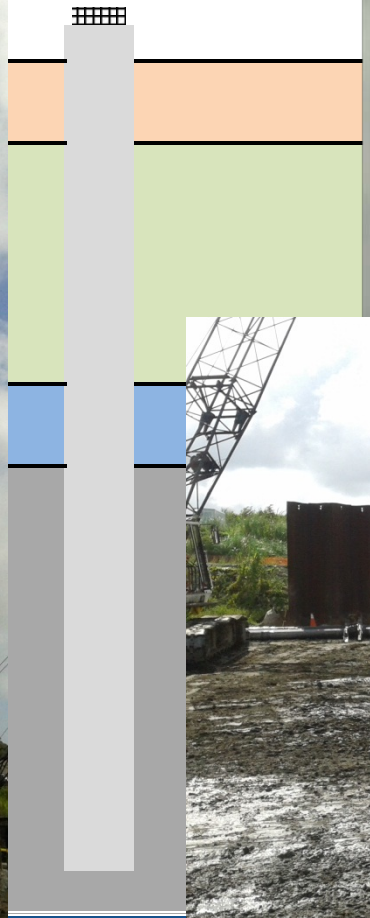
Fuente: Autoridad del Canal de Panamá

Puente sobre el Canal en el lado Atlántico

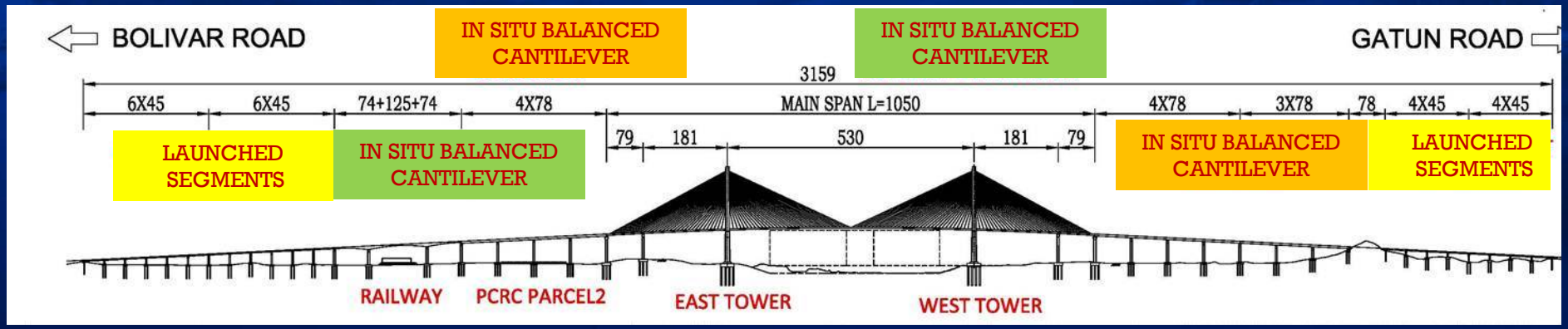
Construccion de pilotes

Fuente: Autoridad del Canal de Panamá

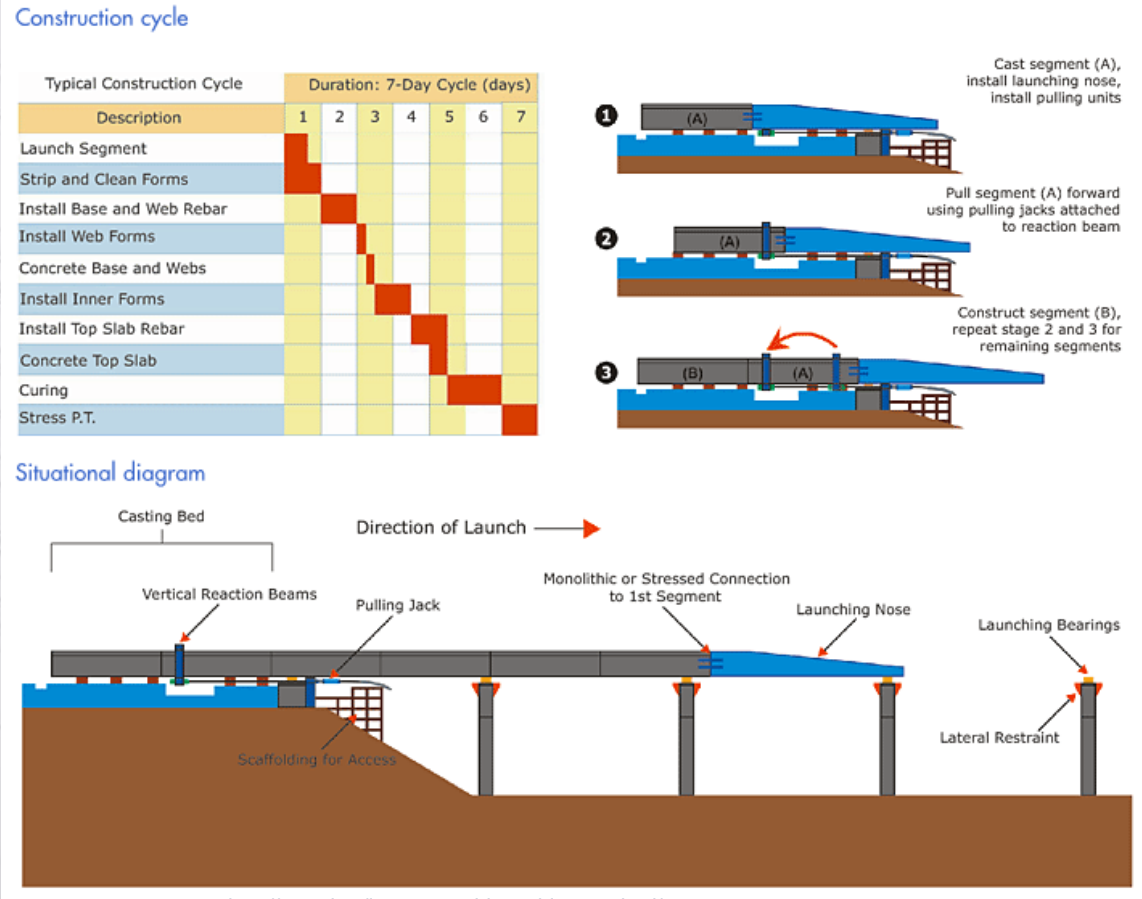
Piling



Metodo Constructivo - Estructuras



VIADUCTOS TRAMOS DE 45M – MÉTODO DE LANZADO



Fuente: http://en.vsl.cz/incremental-launching-method/

Viaductos tramos de 45m – Método de lanzado

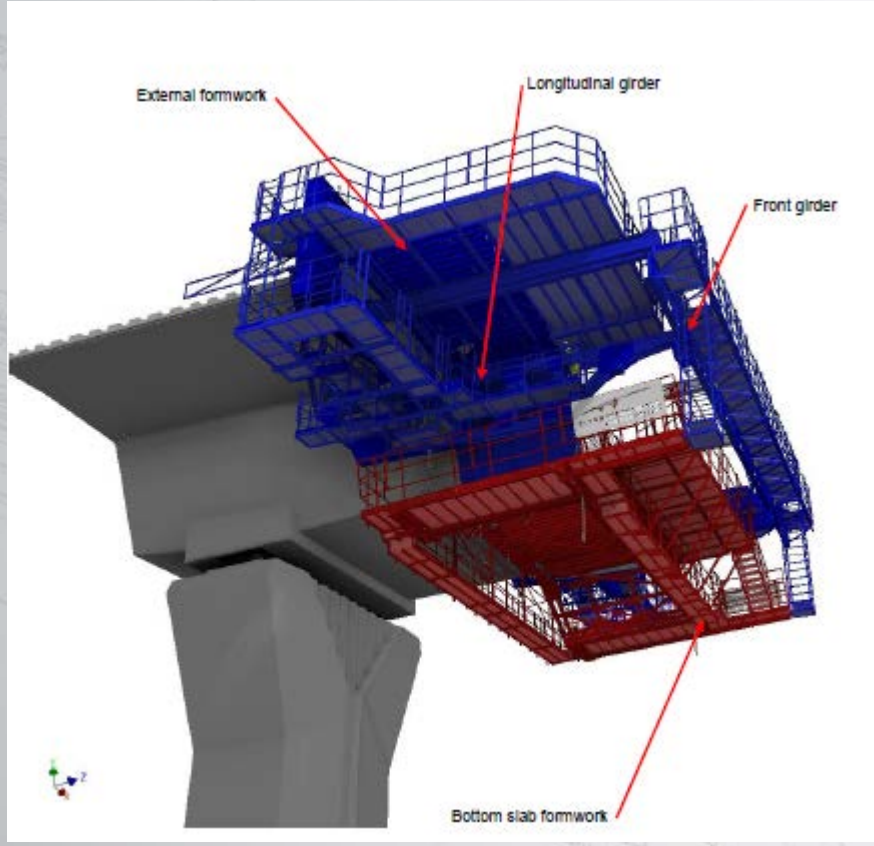
Secuencia de construcción

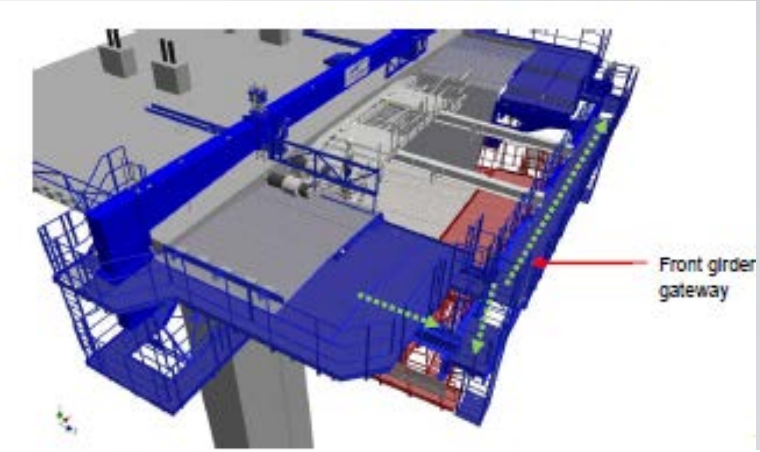
Viaductos tramos de 45m – Método de lanzado

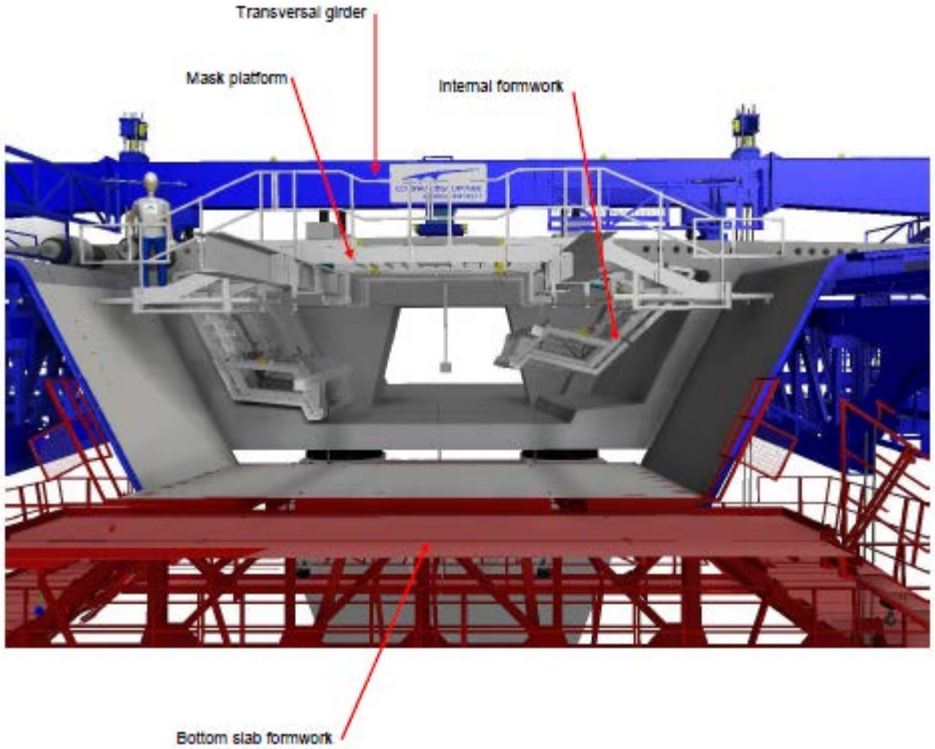
SECUENCIA DE CONSTRUCCIÓN

VIADUCTOS - MÉTODO EN CANTO LIBRE BALANCEADO

FORMALETA







Puente sobre el Canal en el lado Atlántico

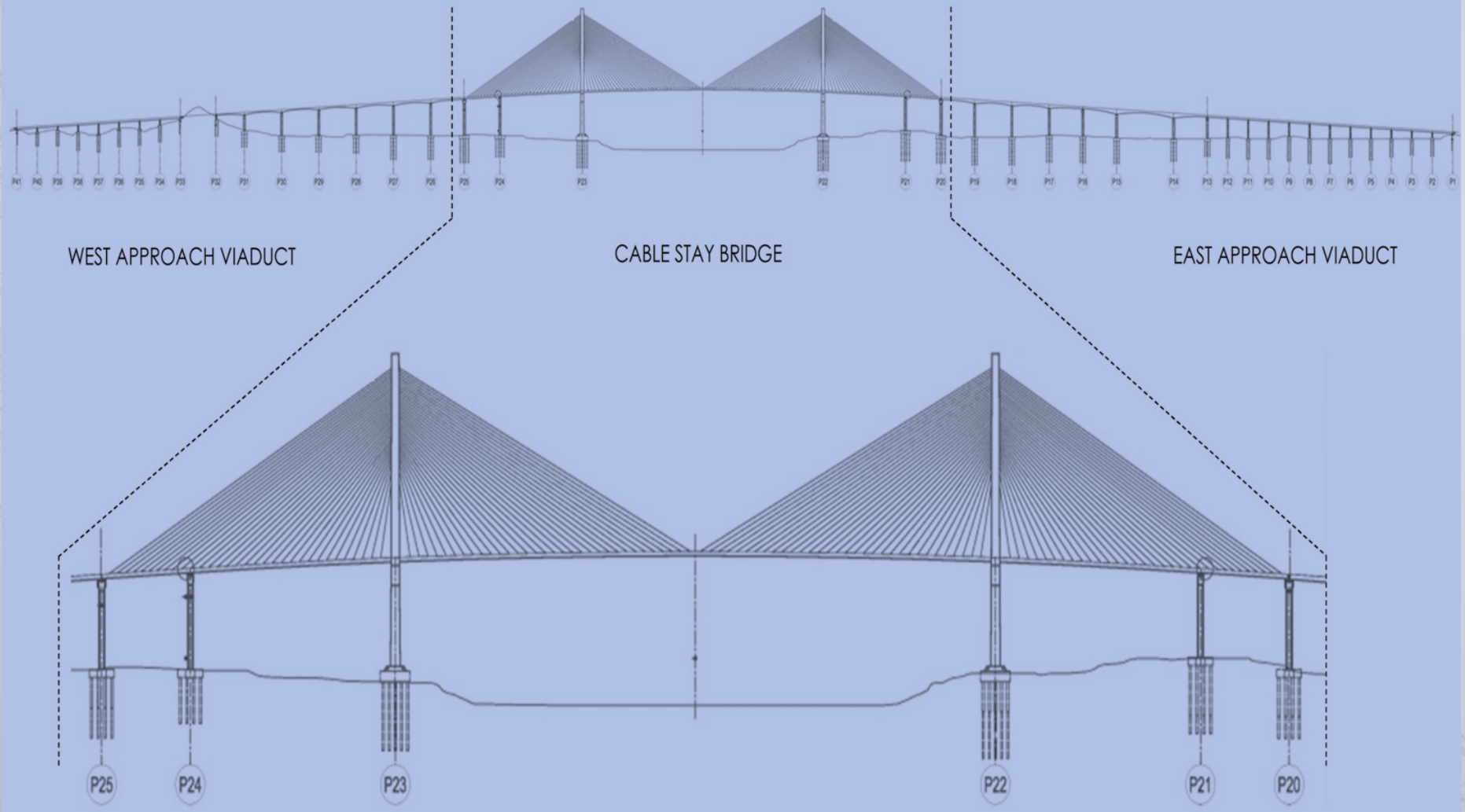
Metodo Constructivo
Tramo atirantado

Fuente: Autoridad del Canal de Panamá

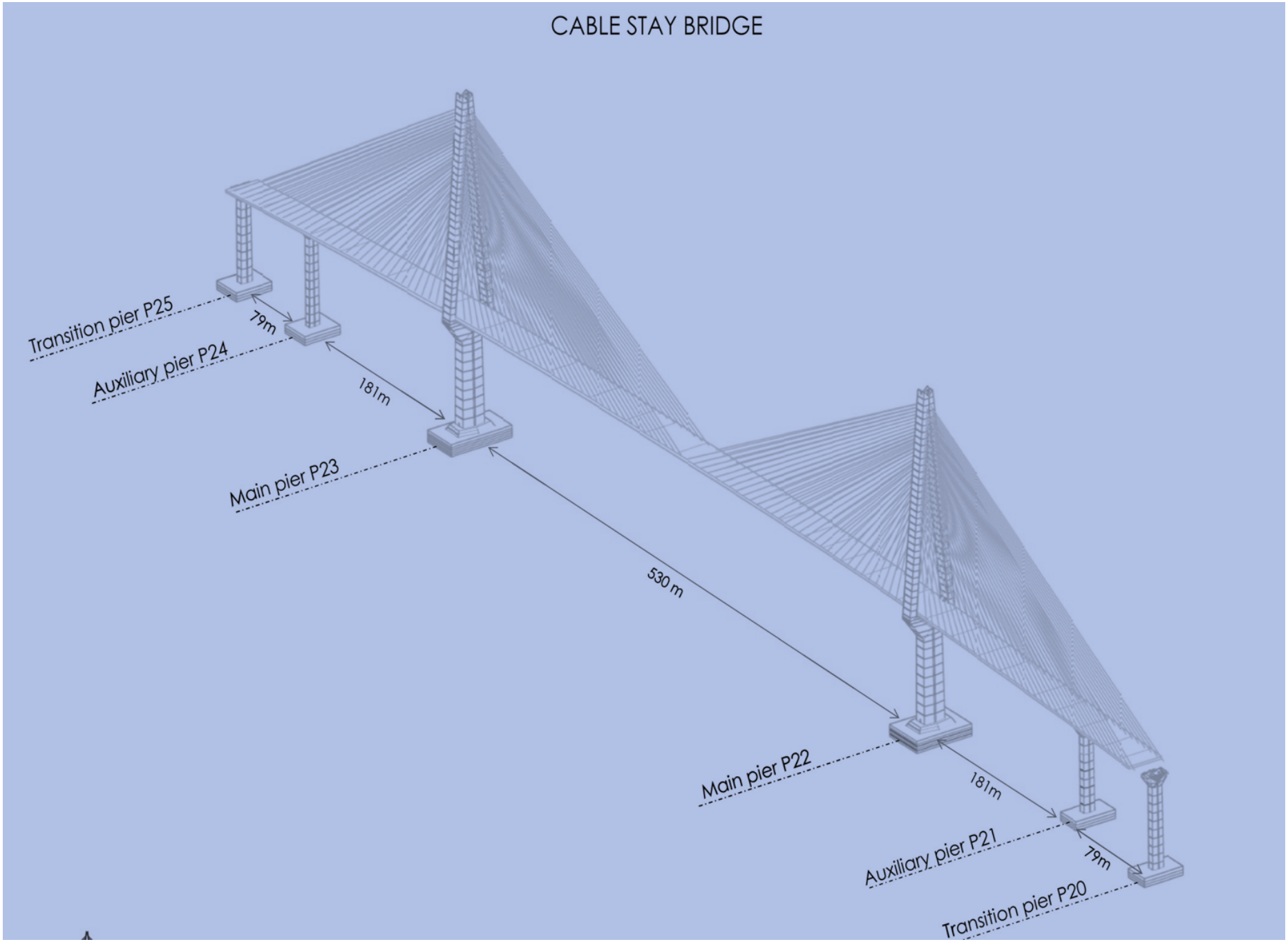
CABLE STAY BRIDGE

OR

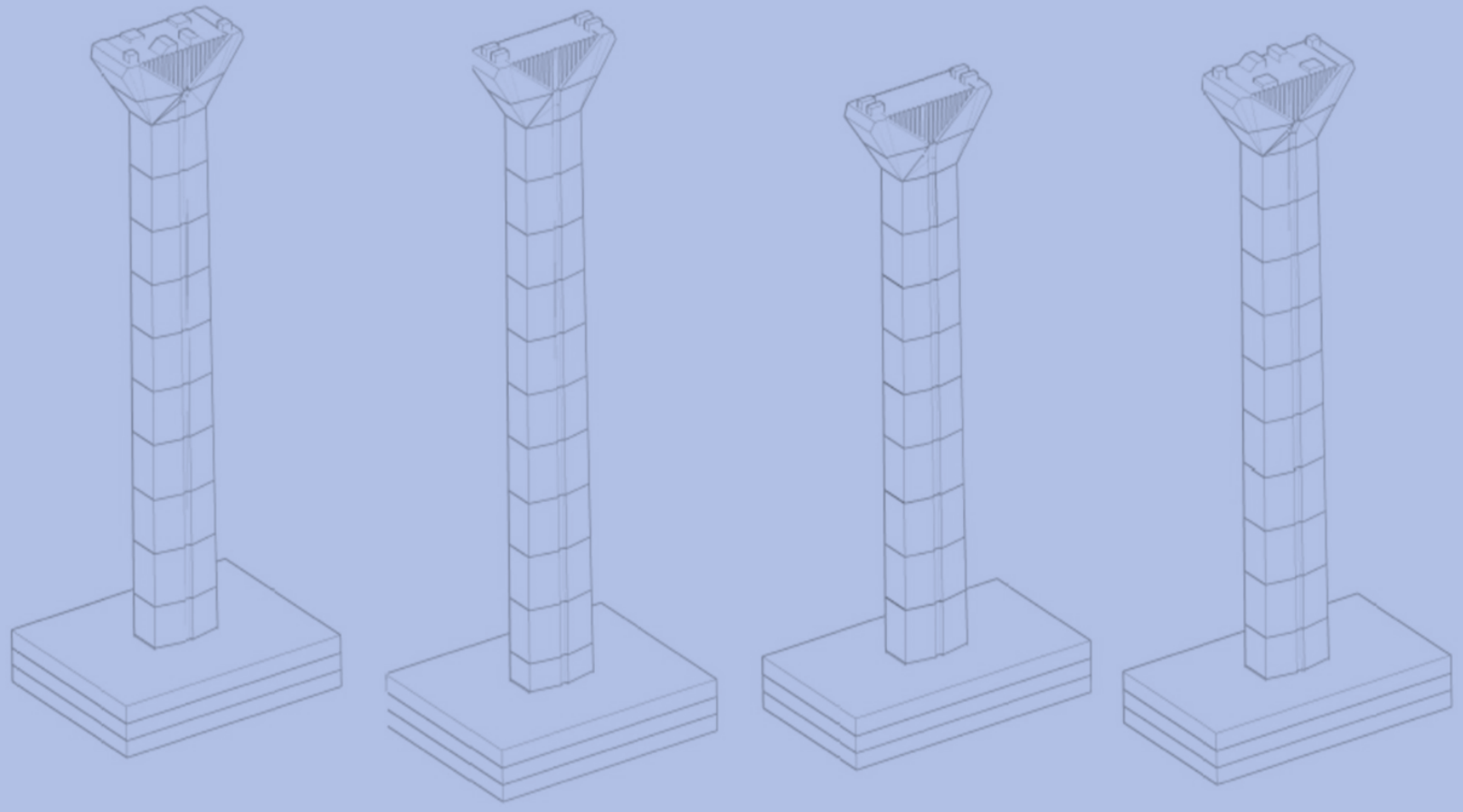
MAIN BRIDGE



CABLE STAY BRIDGE

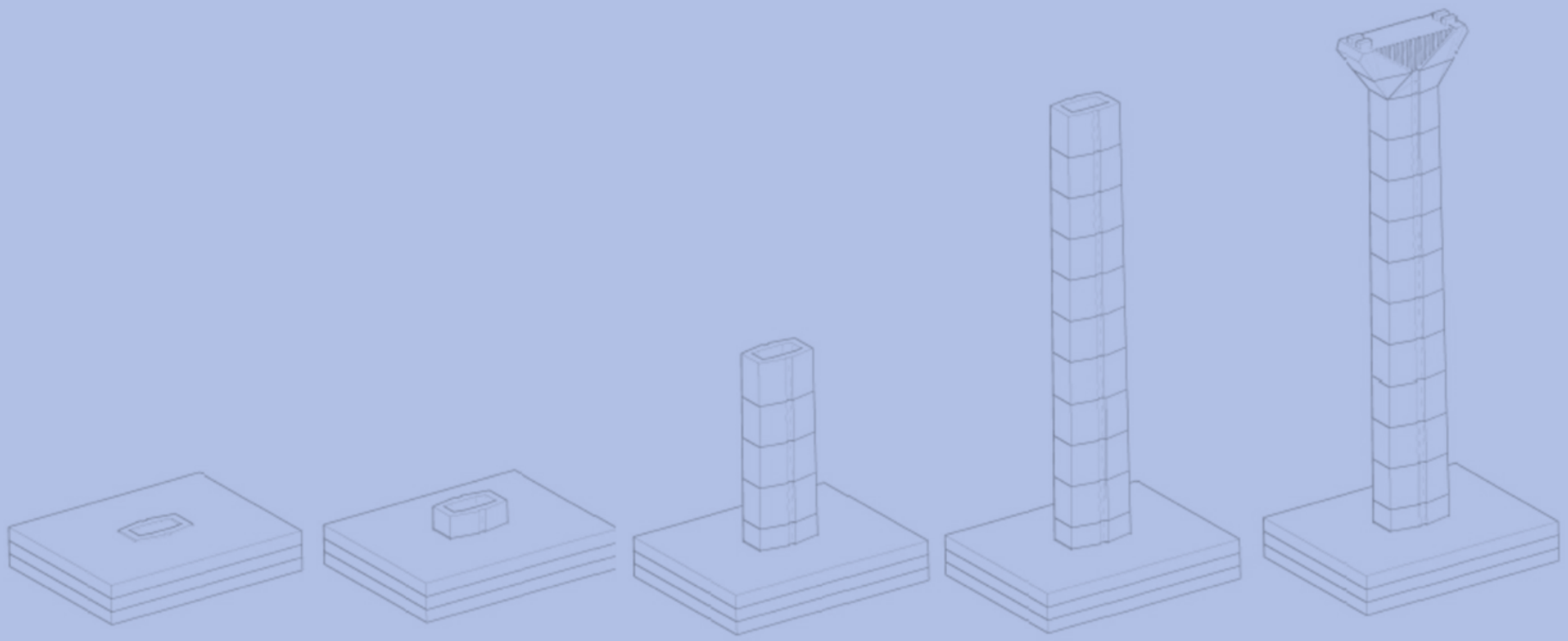


Transition and auxiliary piers



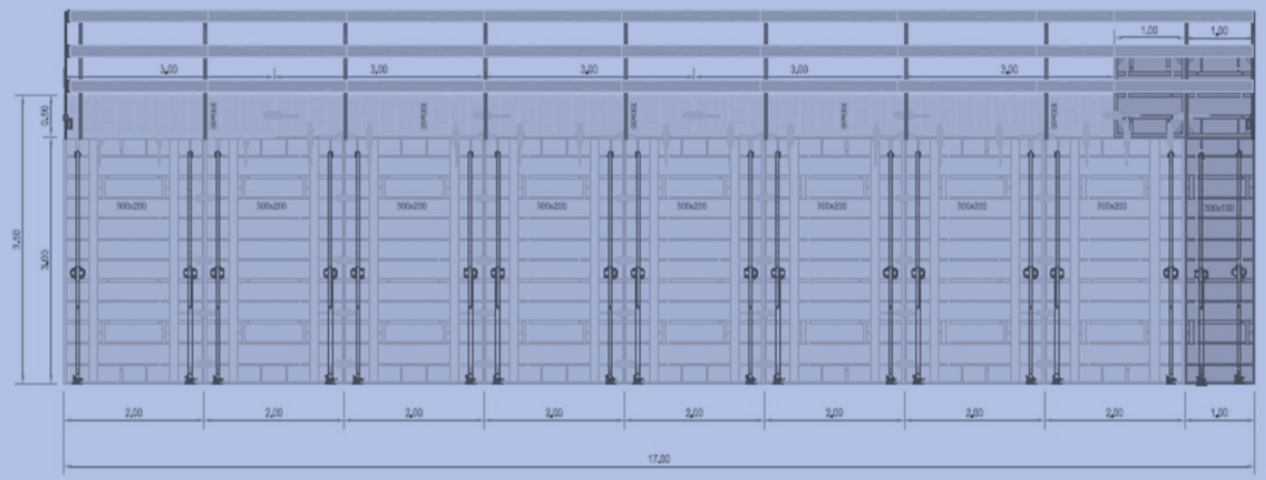
Transition and auxiliary piers

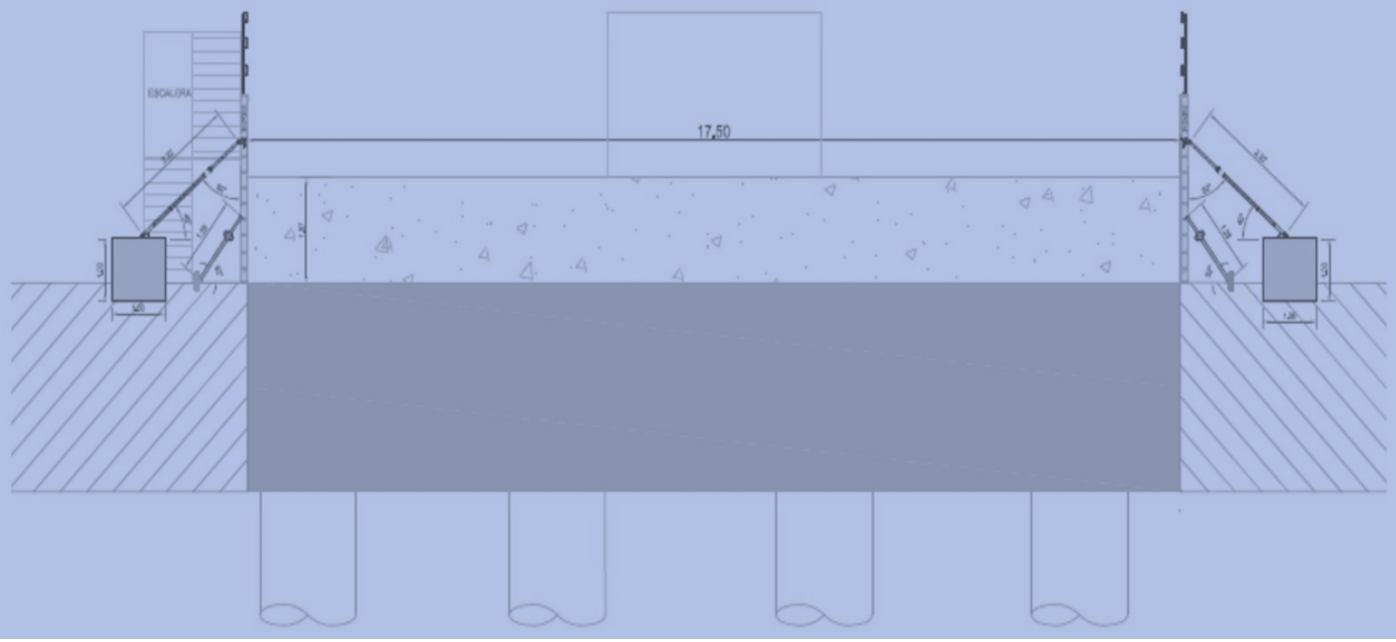
General sequence of construction



Transition and auxiliary piers

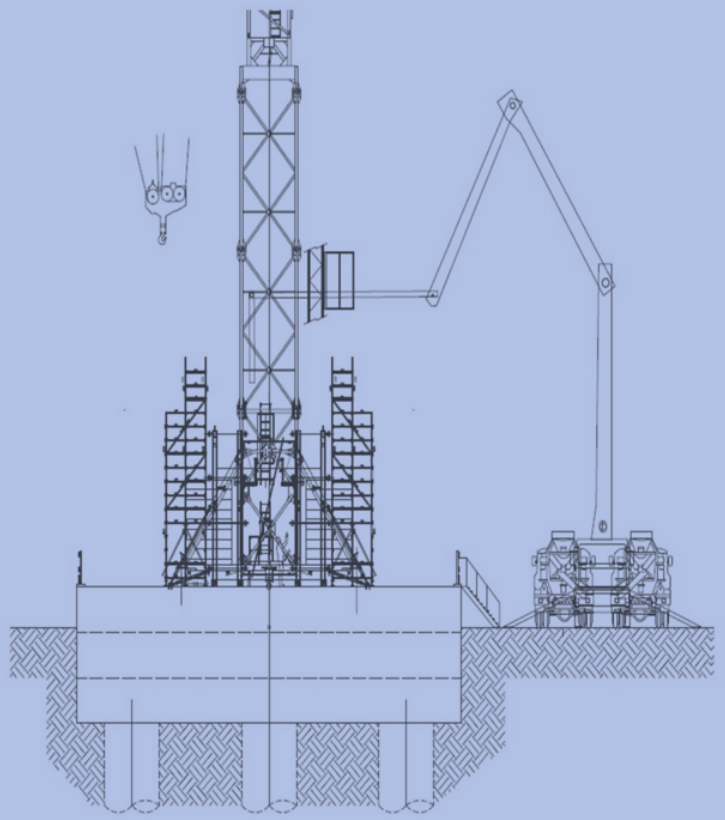
Pile cap construction

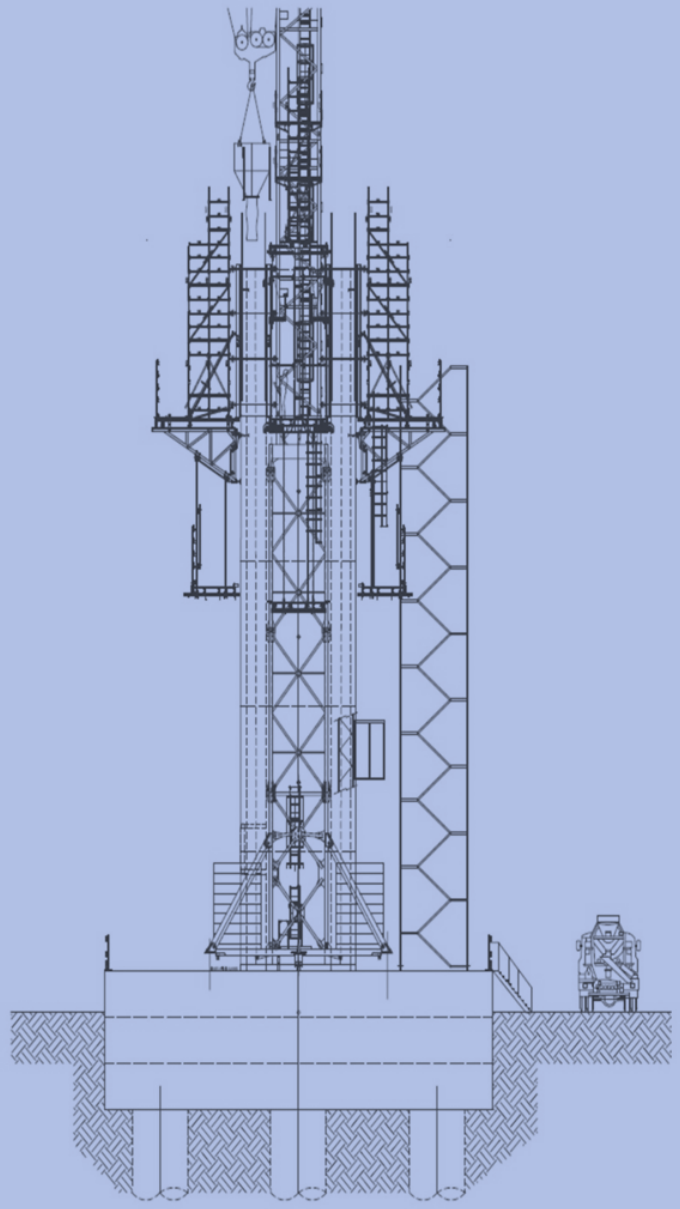




Transition and auxiliary piers

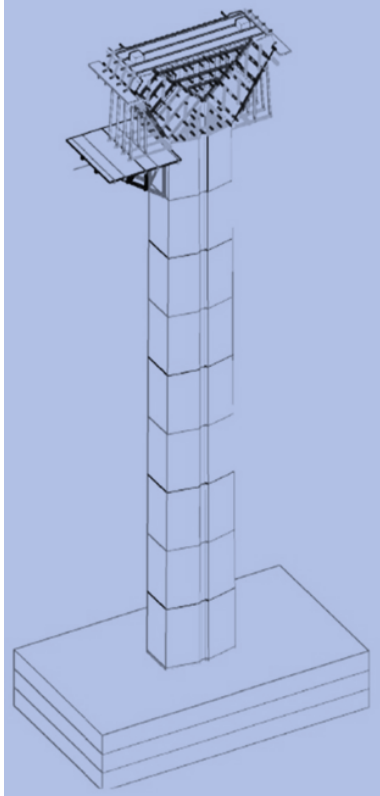
Shaft construction

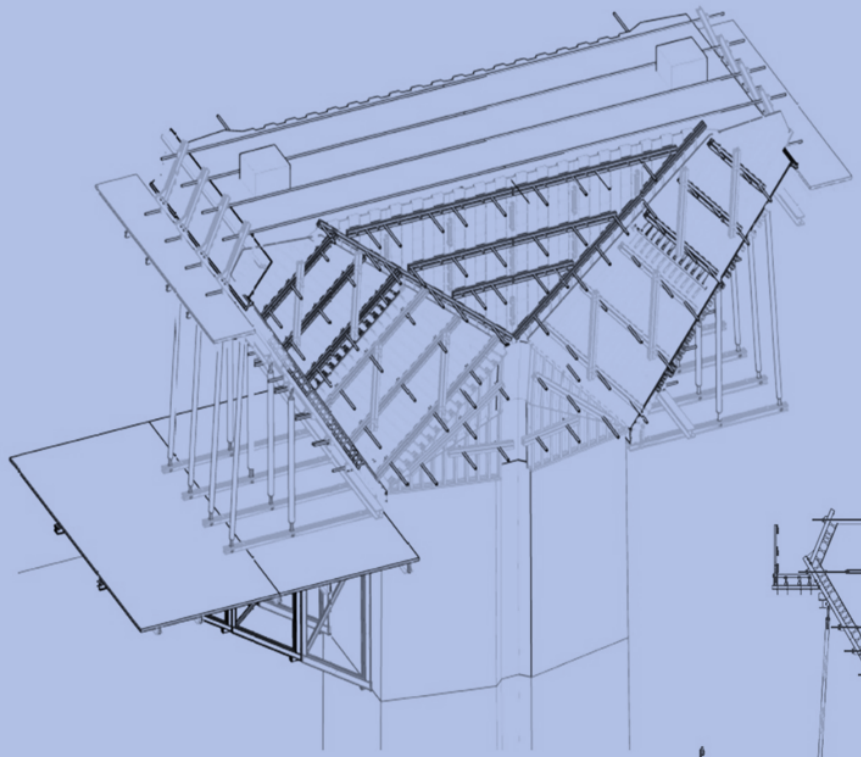


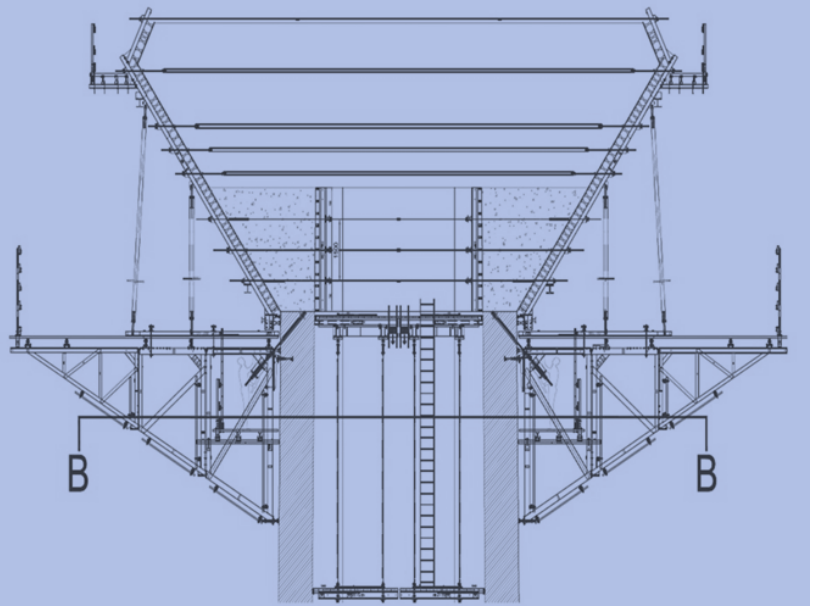


Transition and auxiliary piers

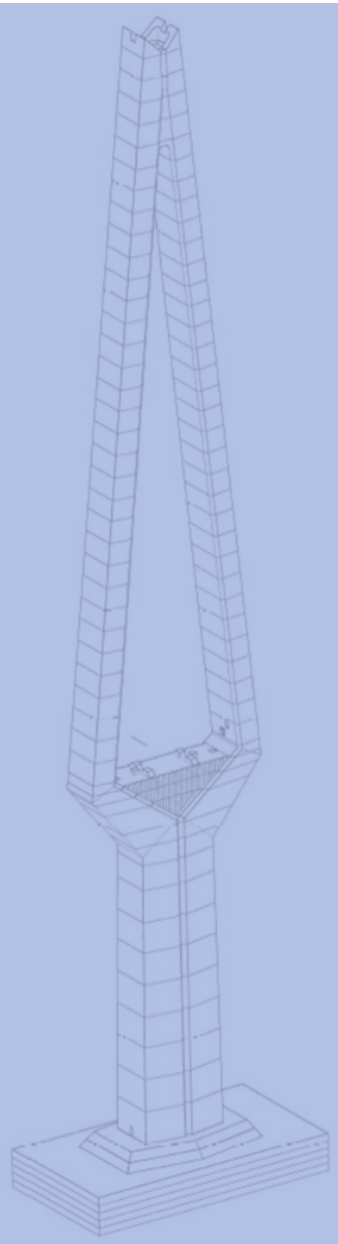
Pier head construction



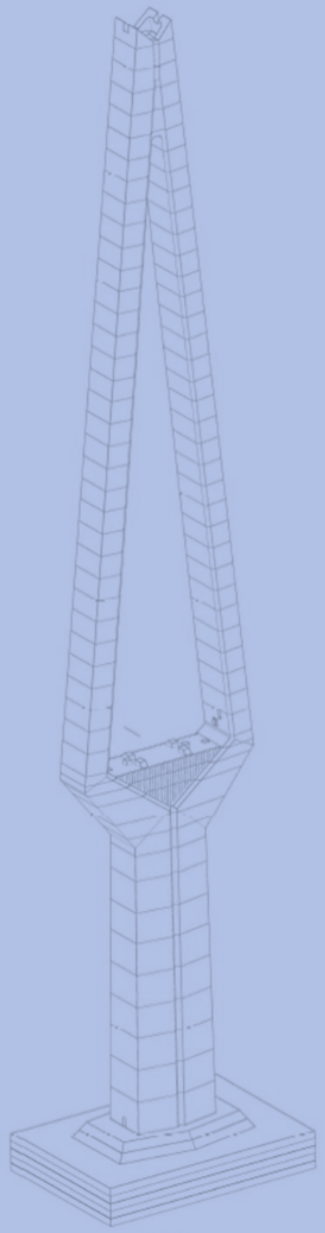




Main piers



P23

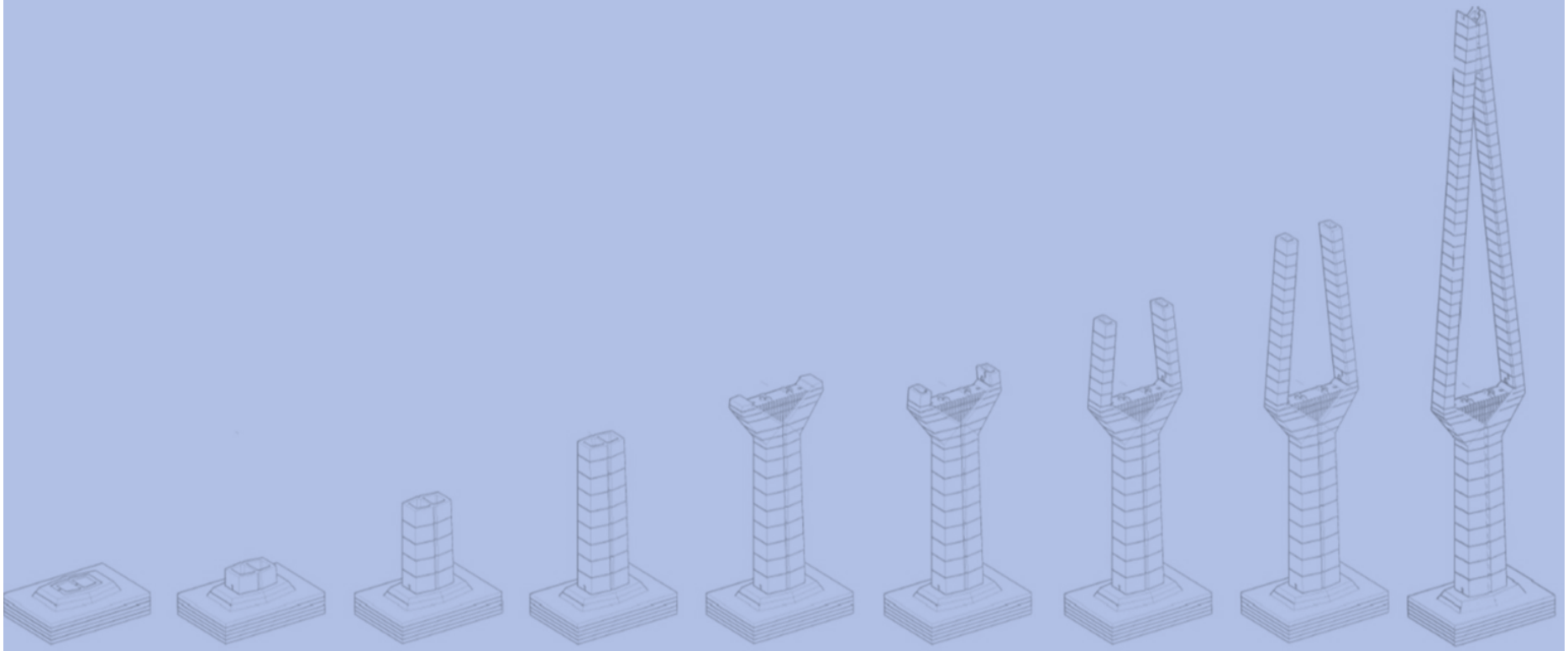


P22

Main piers

General sequence

of construction



Pile cap and kicker

Shaft false (first) lift

Shaft current lifts

Shaft last lift

Delta shape head

First leg section

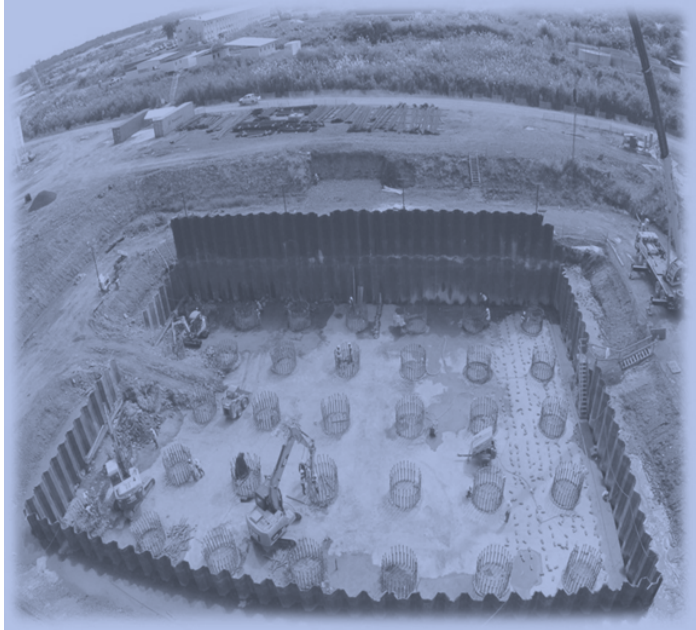
Current leg sections

Leg sections and cable stay

Tower head

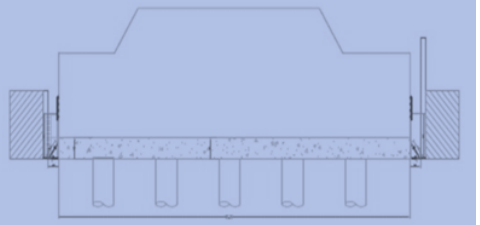
Main piers

Pile cap and kicker construction

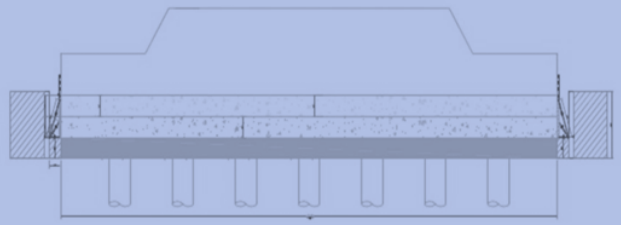


P22 in preparation for pile cap construction

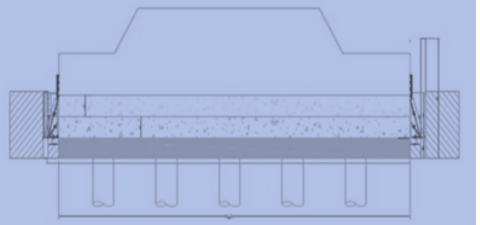
FIRST POUR– SECTION A–A



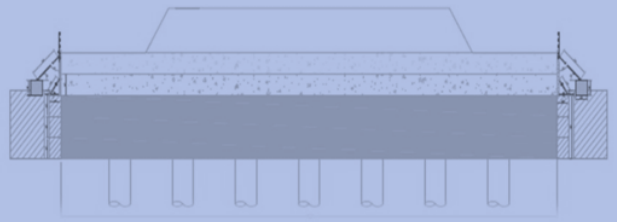
FIRST POUR– SECTION B–B

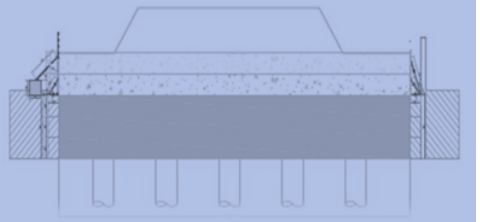


SECOND AND THIRD POUR – SECTION A–A



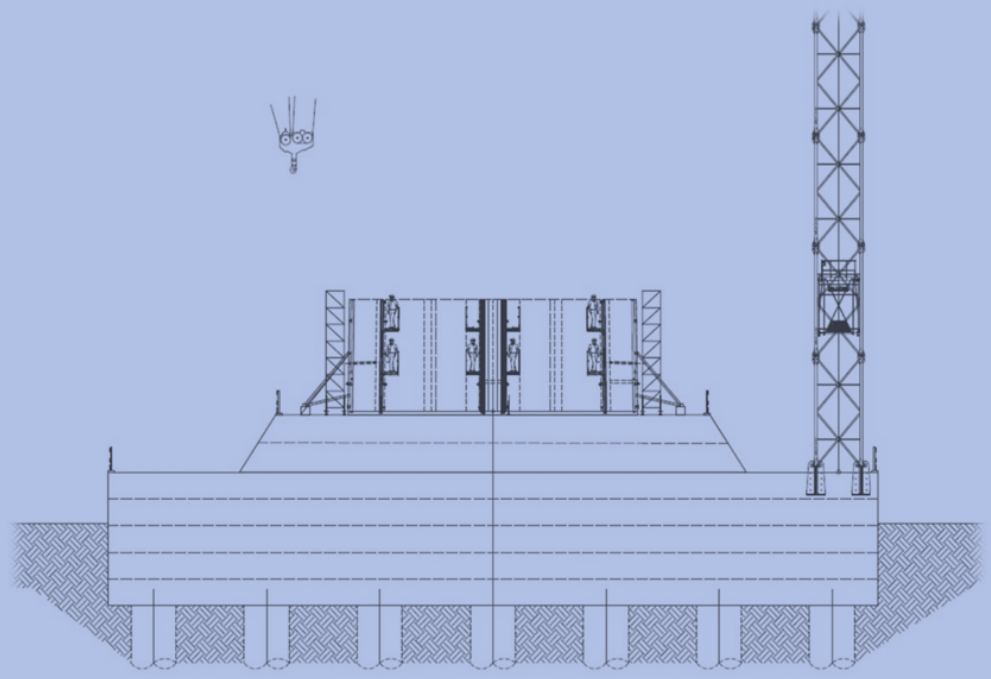
SECOND AND THIRD POUR – SECTION B–B

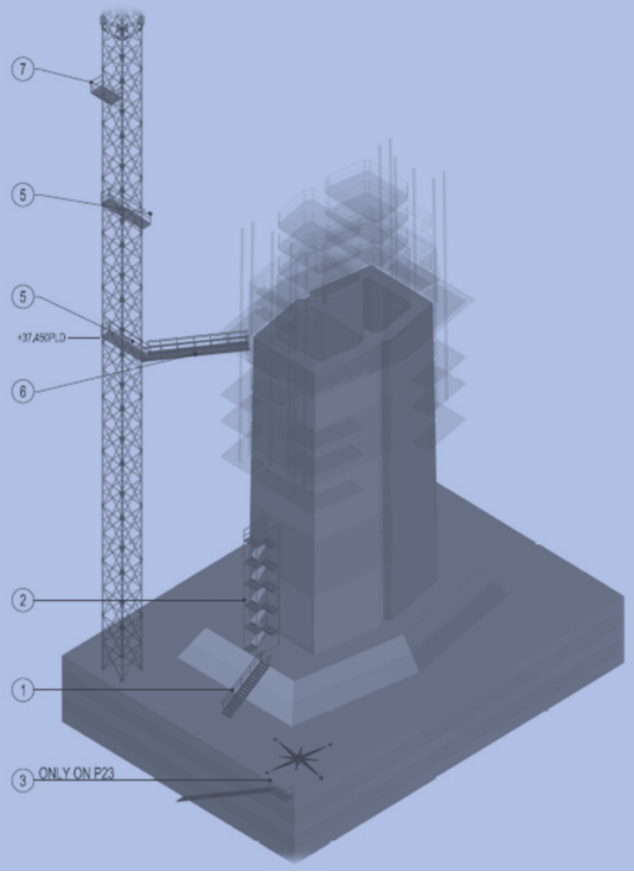




Main piers

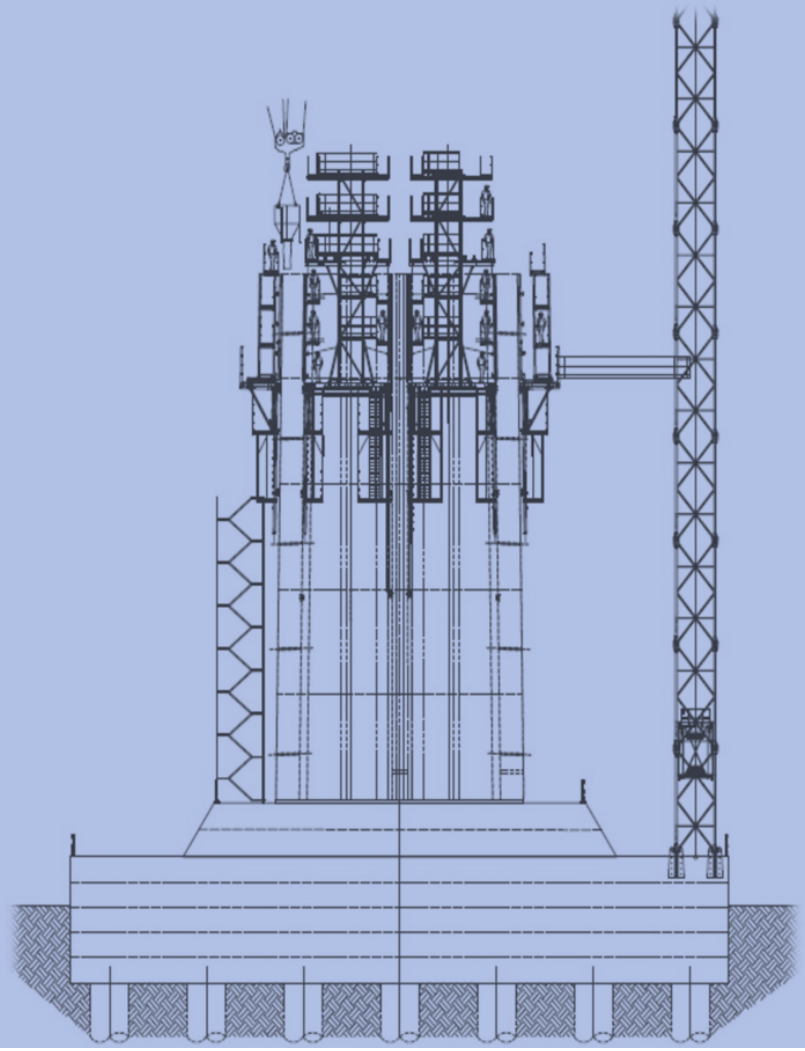
Shaft false lift construction

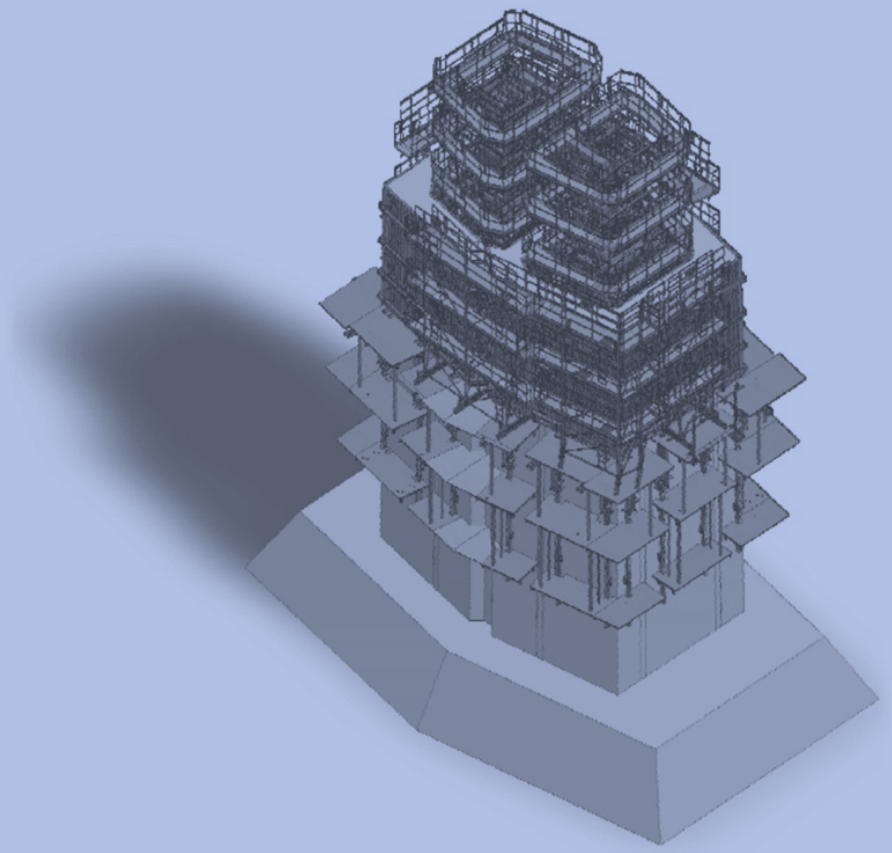


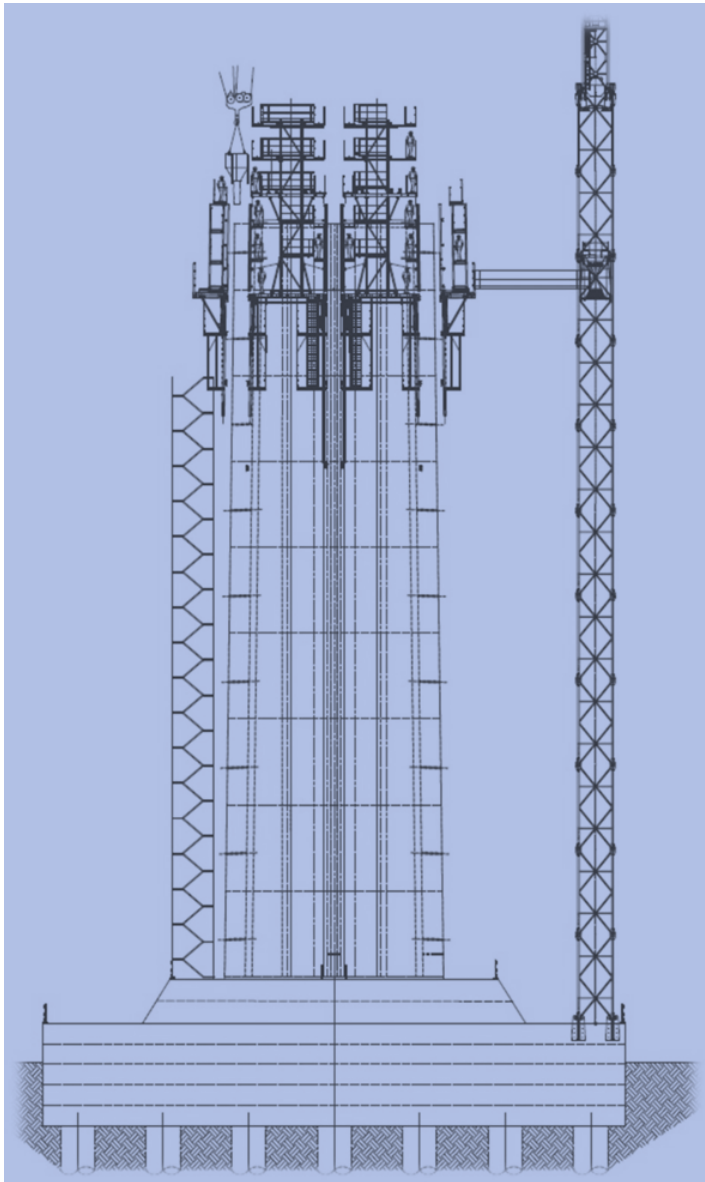


Main piers

Shaft current lift construction

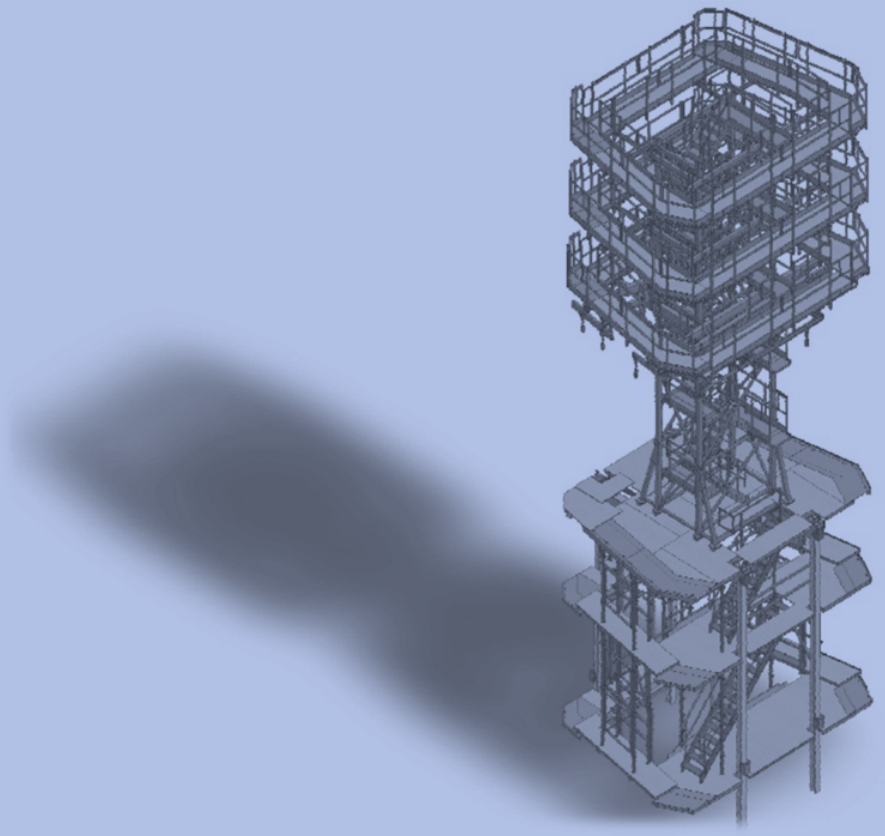






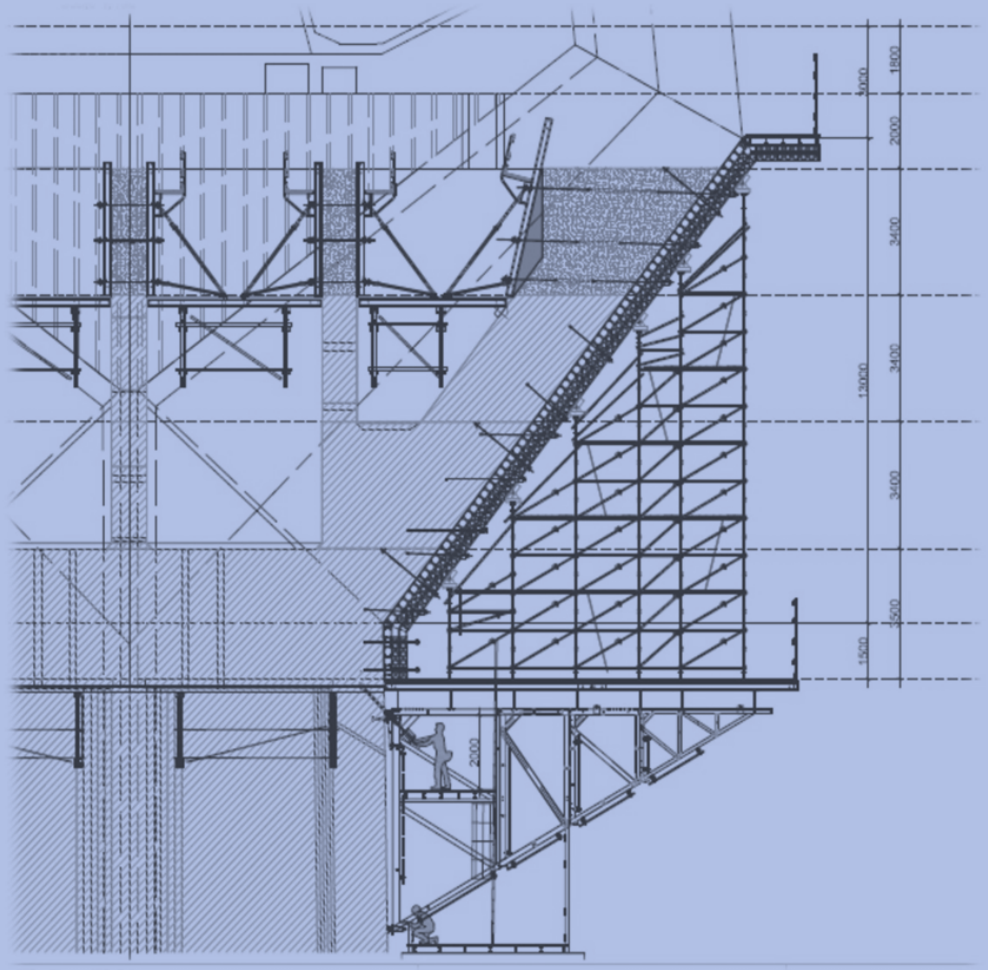
Main piers

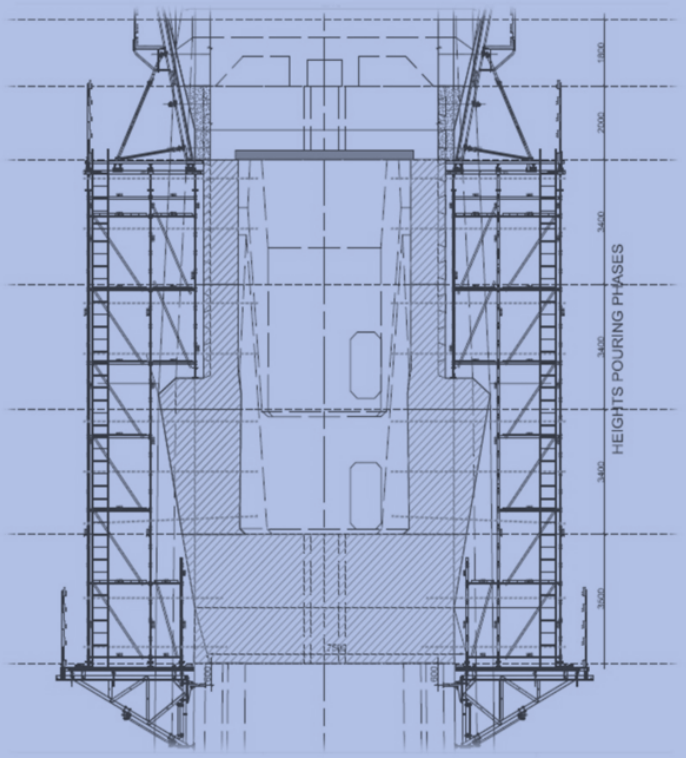
Shaft last lift construction



Main piers

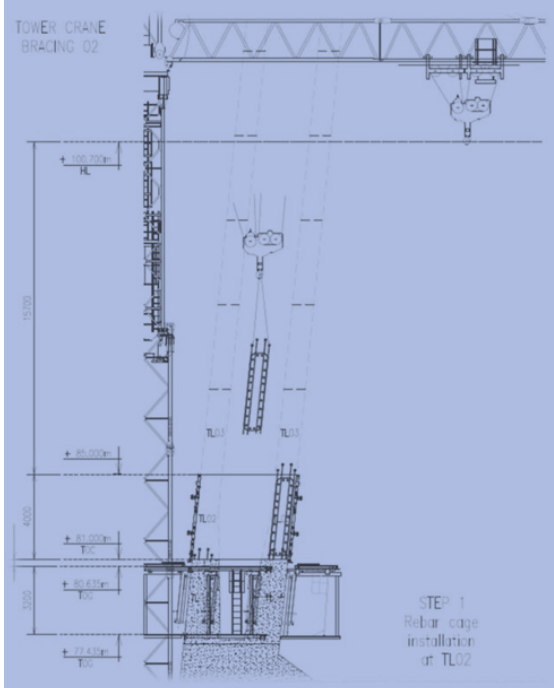
Delta shape head construction

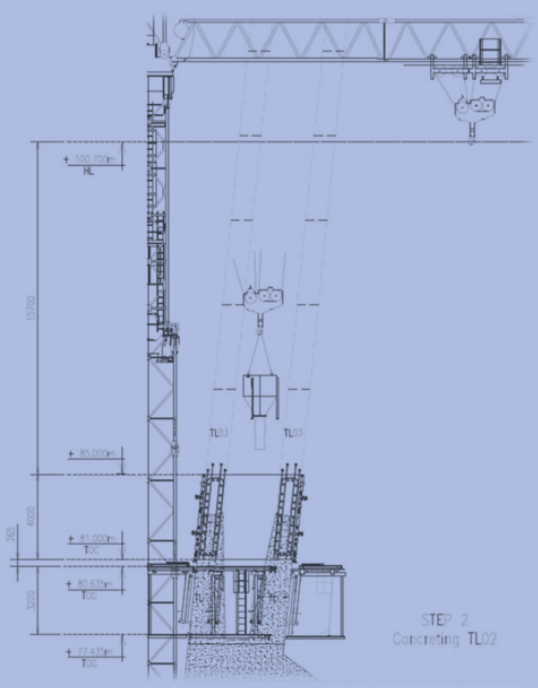


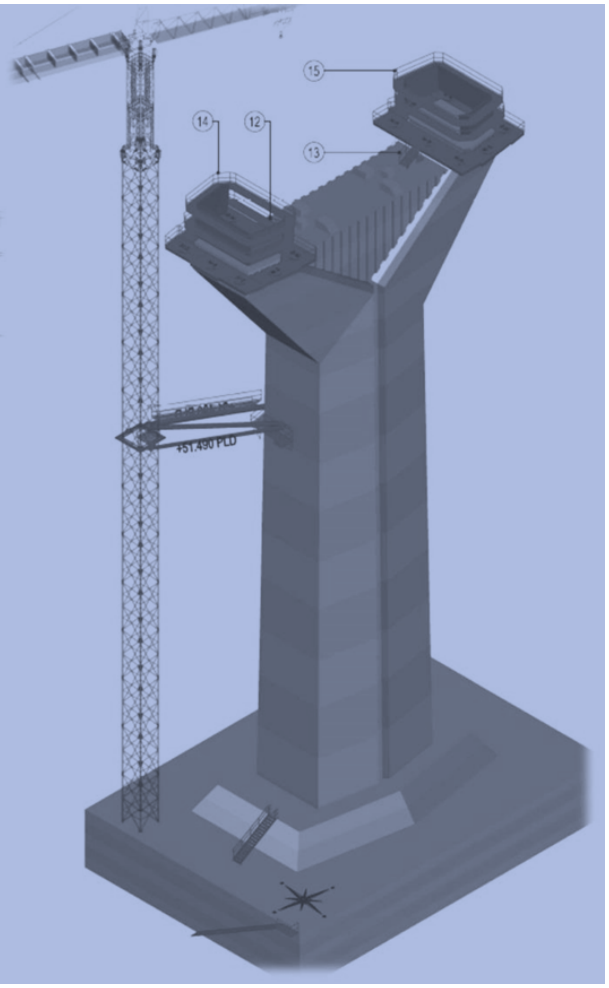


Main piers

First leg section construction

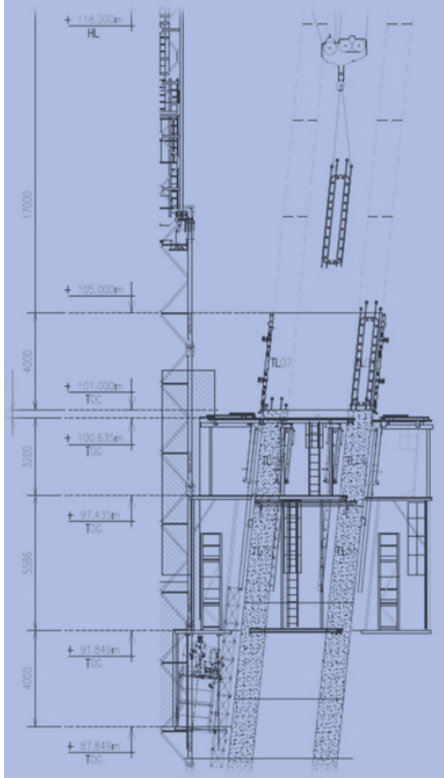


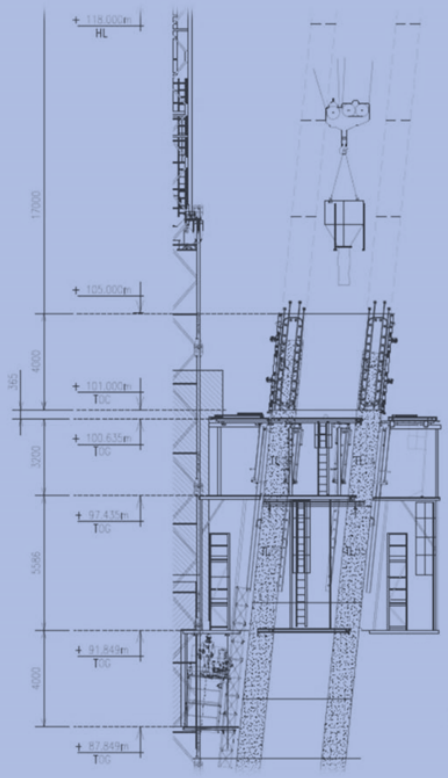


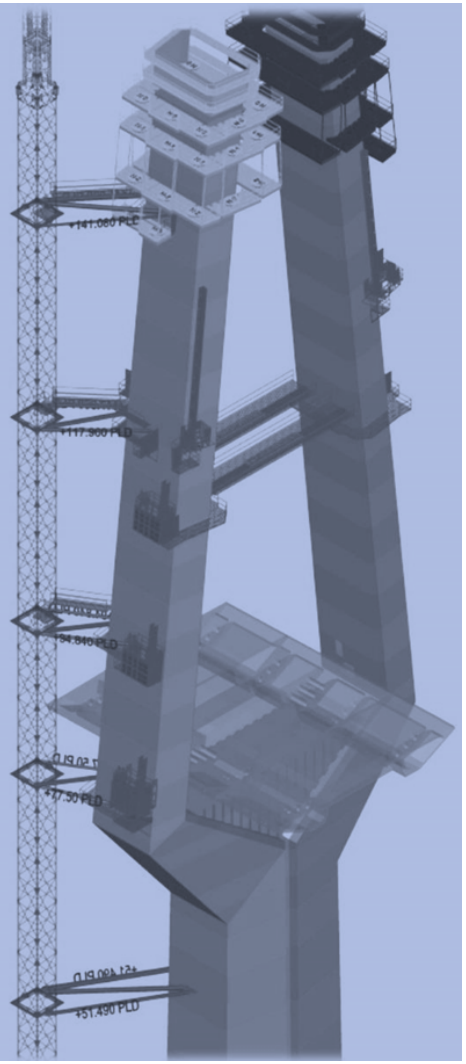


Main piers

Current leg section construction

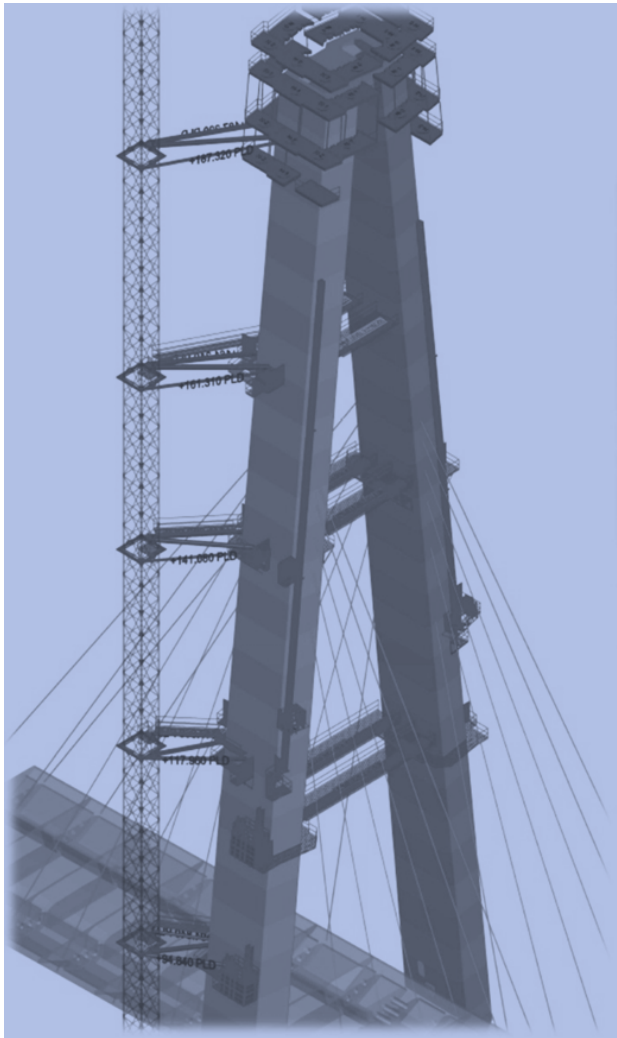


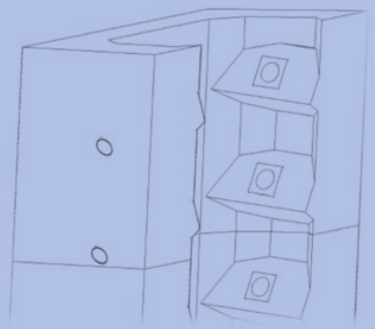


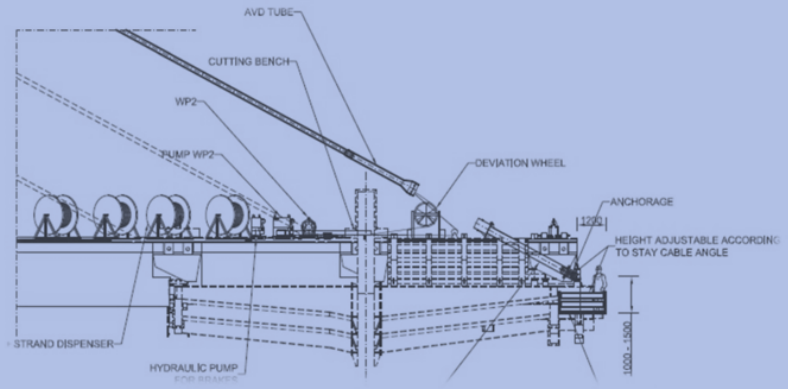


Main piers

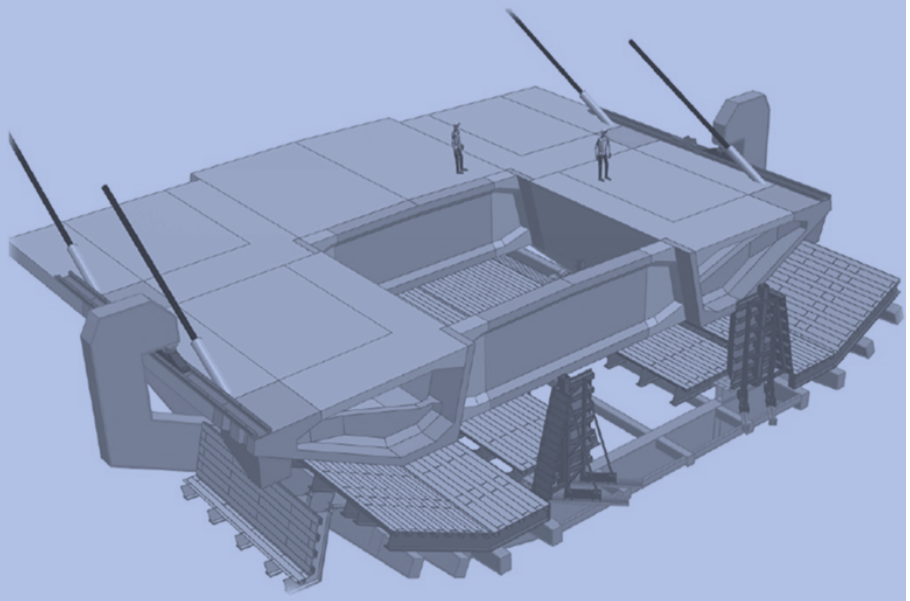
Cable stay installation







Main bridge deck



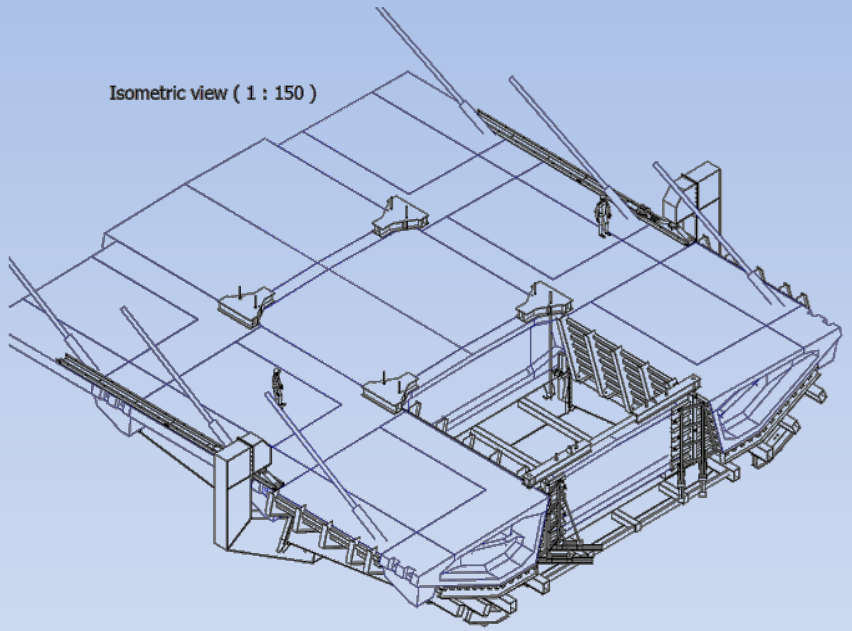
Atlantic Bridge, Panamá

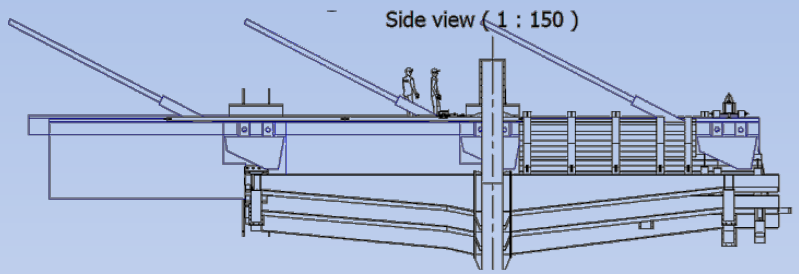
Main Bridge
Form Traveler

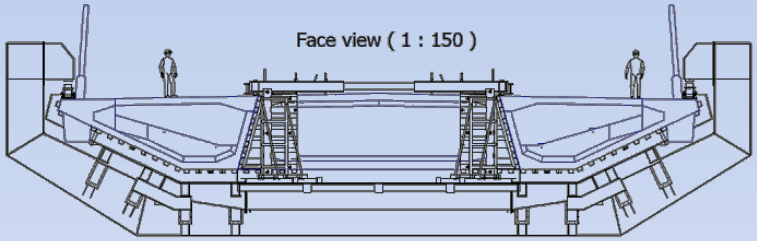
ACP
AUTORIDAD DEL CANAL DE PANAMÁ

PASA
PUENTE ATLÁNTICO S. A.

General Layout





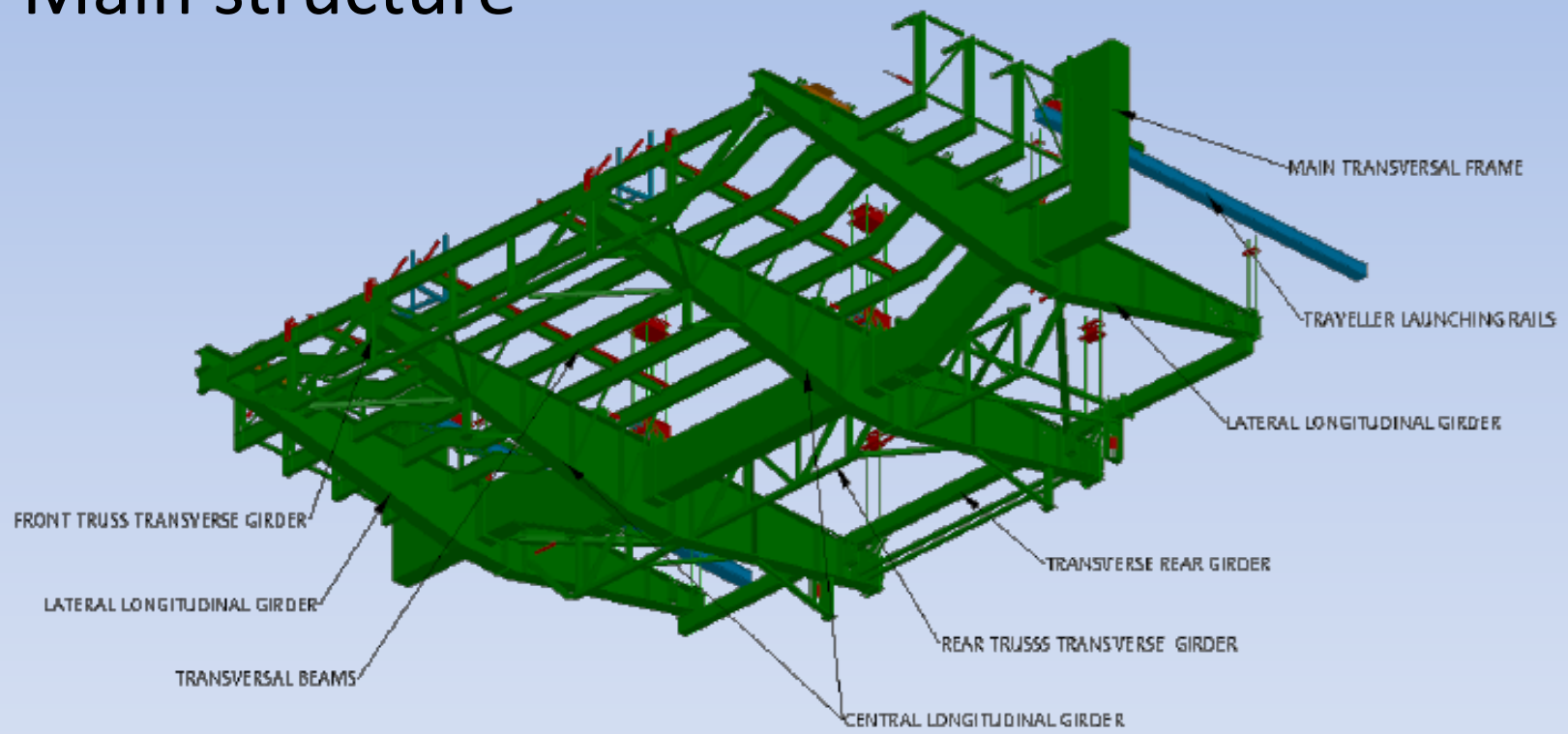


- ***Deck Width : 23.60m***

- ***Segments :*** ***<u>Height :</u> 2.834m*** ***<u>Total Nb :</u> 133 Segments***
  <u>Weight :</u> 300 tons
  <u>Lenght :</u> 12m (SOP), 7&8m (Standard) and 6m (Stich)

Overview of Rúbrica FT

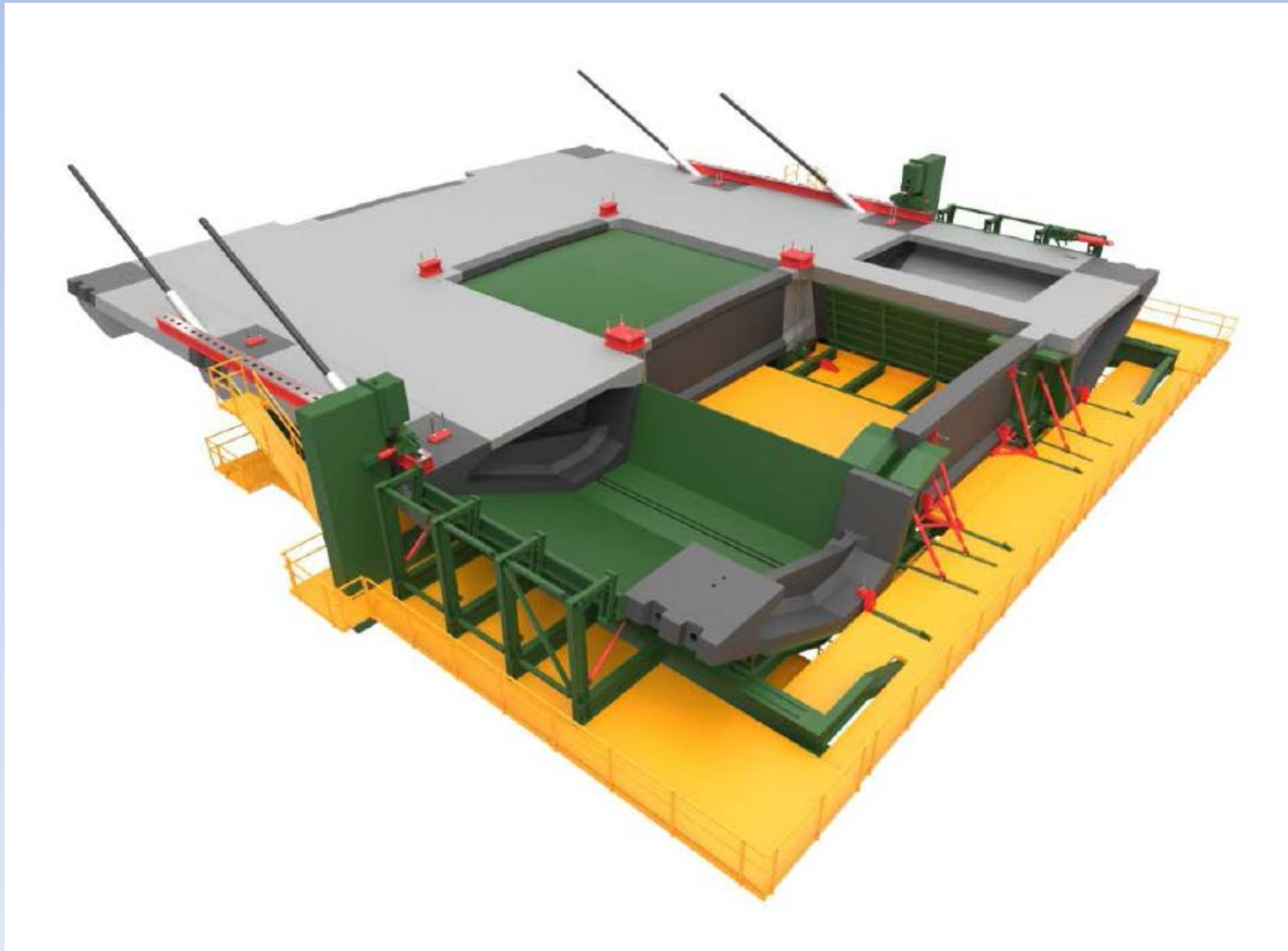
- Main structure



- ***4 longitudinal beams for stability & Lightness***

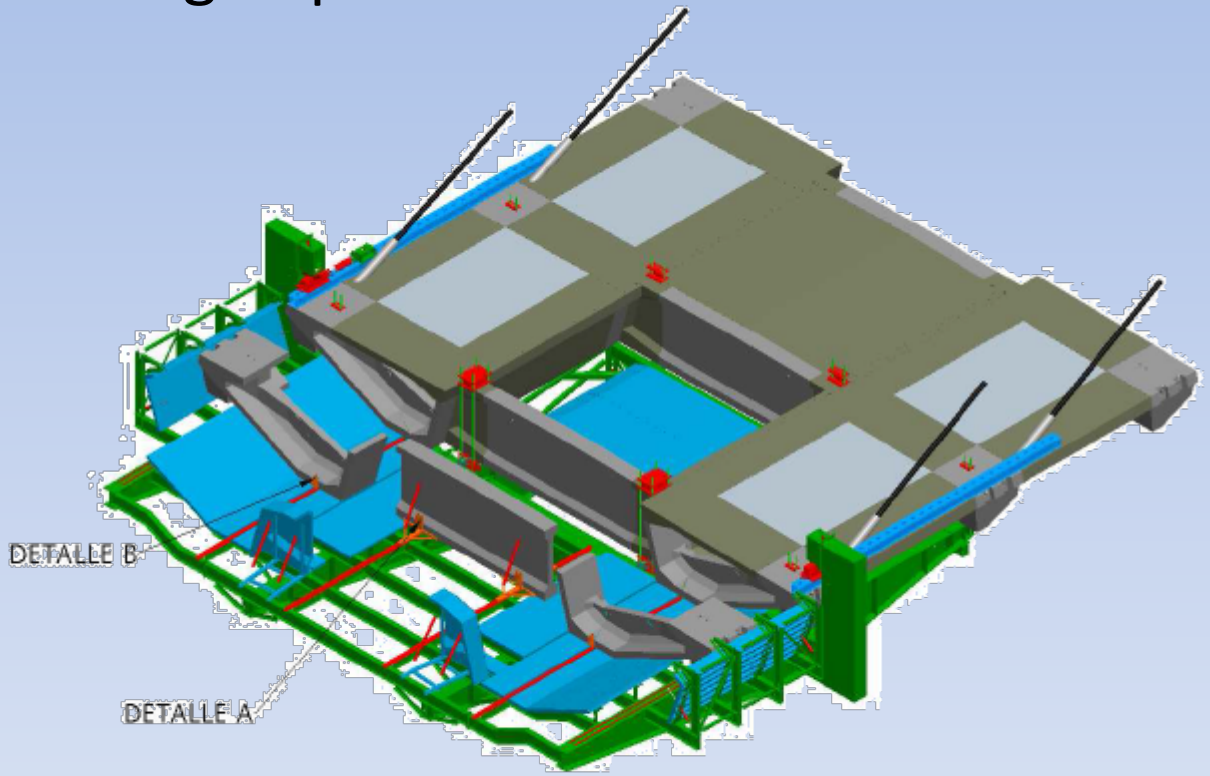
Overview of Rúbrica FT

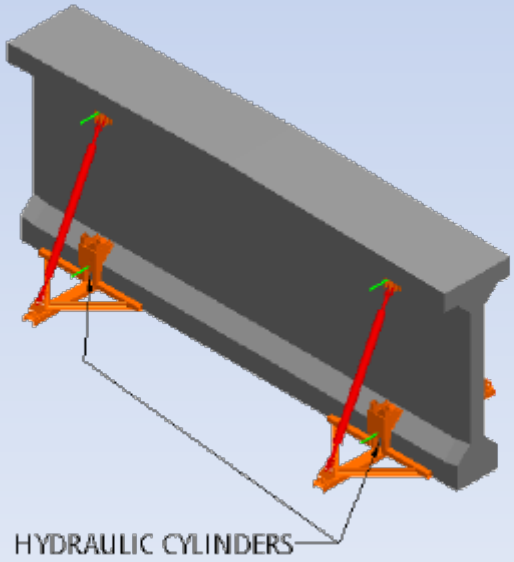
- Main Structure with Panels & Anchoring



Overview of Rúbrica FT

- Sliding of precast elements

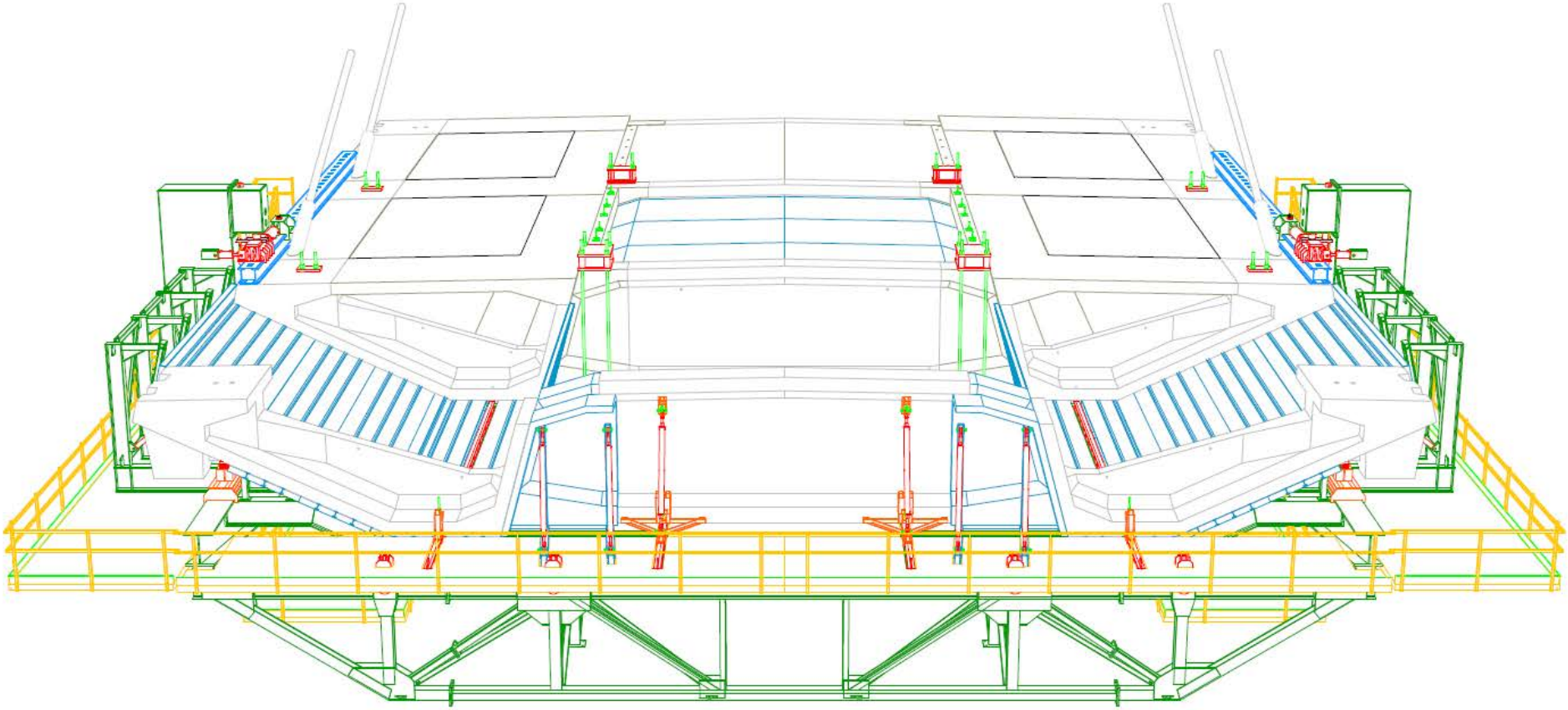




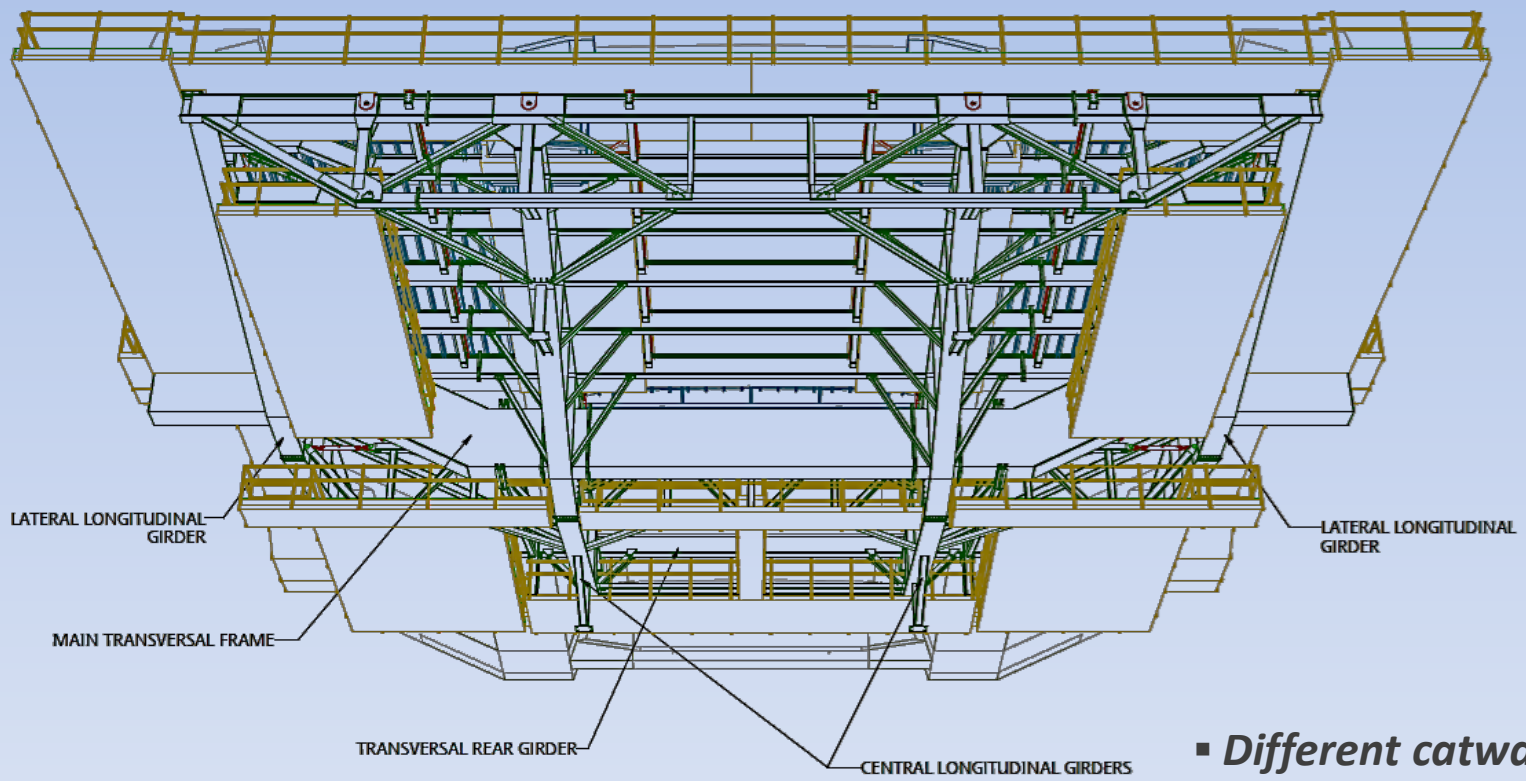
- ***Sliding of precast elements once TF is in place & strenghtened.***

- ***Safer & More reliable proposition***

General View

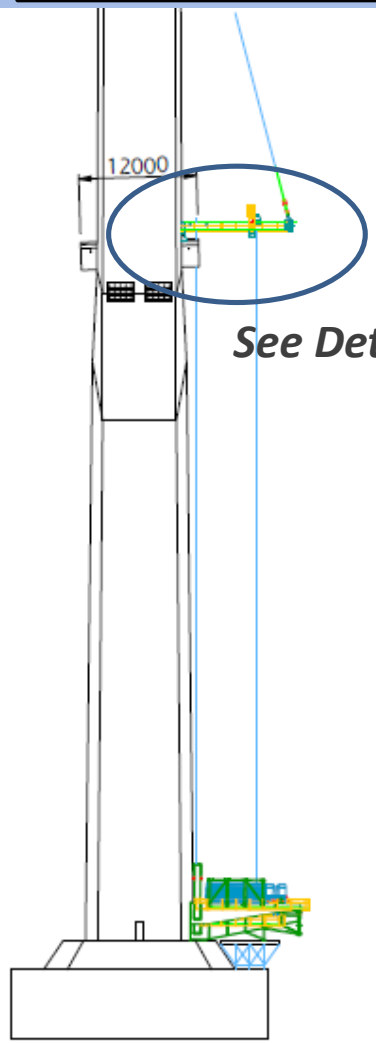


Safety & Accesses

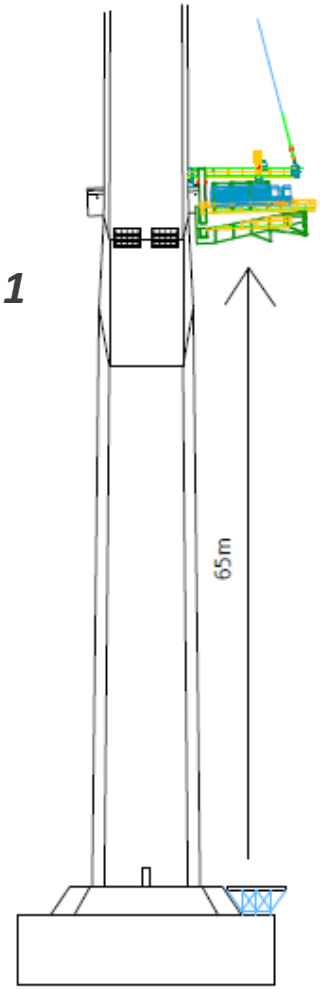


- ***Different catwalks***
- ***Safety net/ Tarpaulin under FT to avoid falling objects***

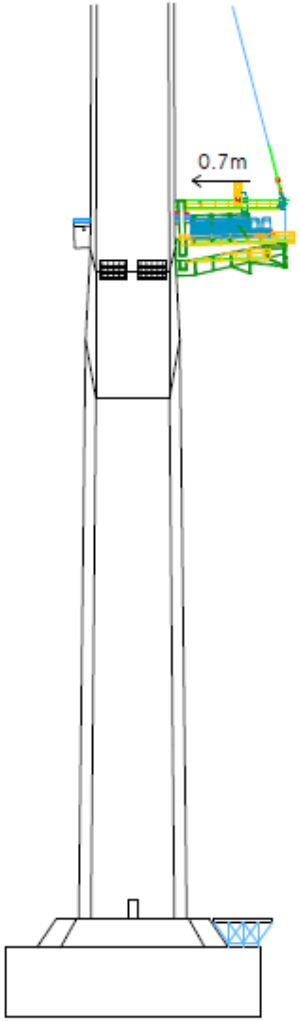
Lifting Sequence (1/2)



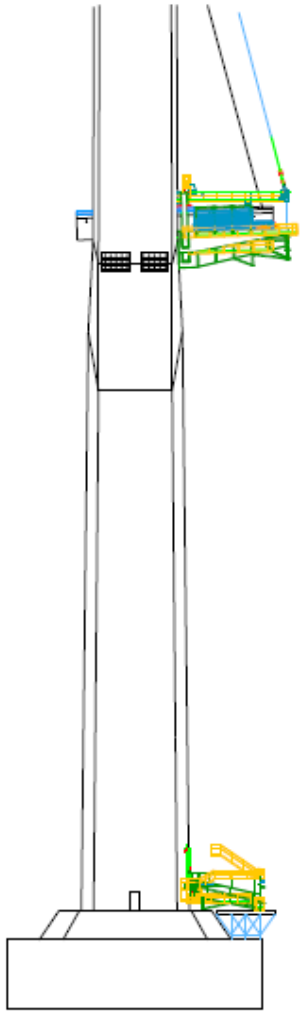
STEP 0:
- PLACE THE HOISTING FRAME
- ASSEMBLY OF THE FRONTAL PART OF THE FT ON THE FALSWORK (GROUND LEVEL)



STEP 1:
- HOISTING OF THE FT APROX. 65 m \WITH 4 STRAND JACKS (2 JACKS OVER THE HOISTING STRUCTURE AND 2 JACKS OVER THE DECK)

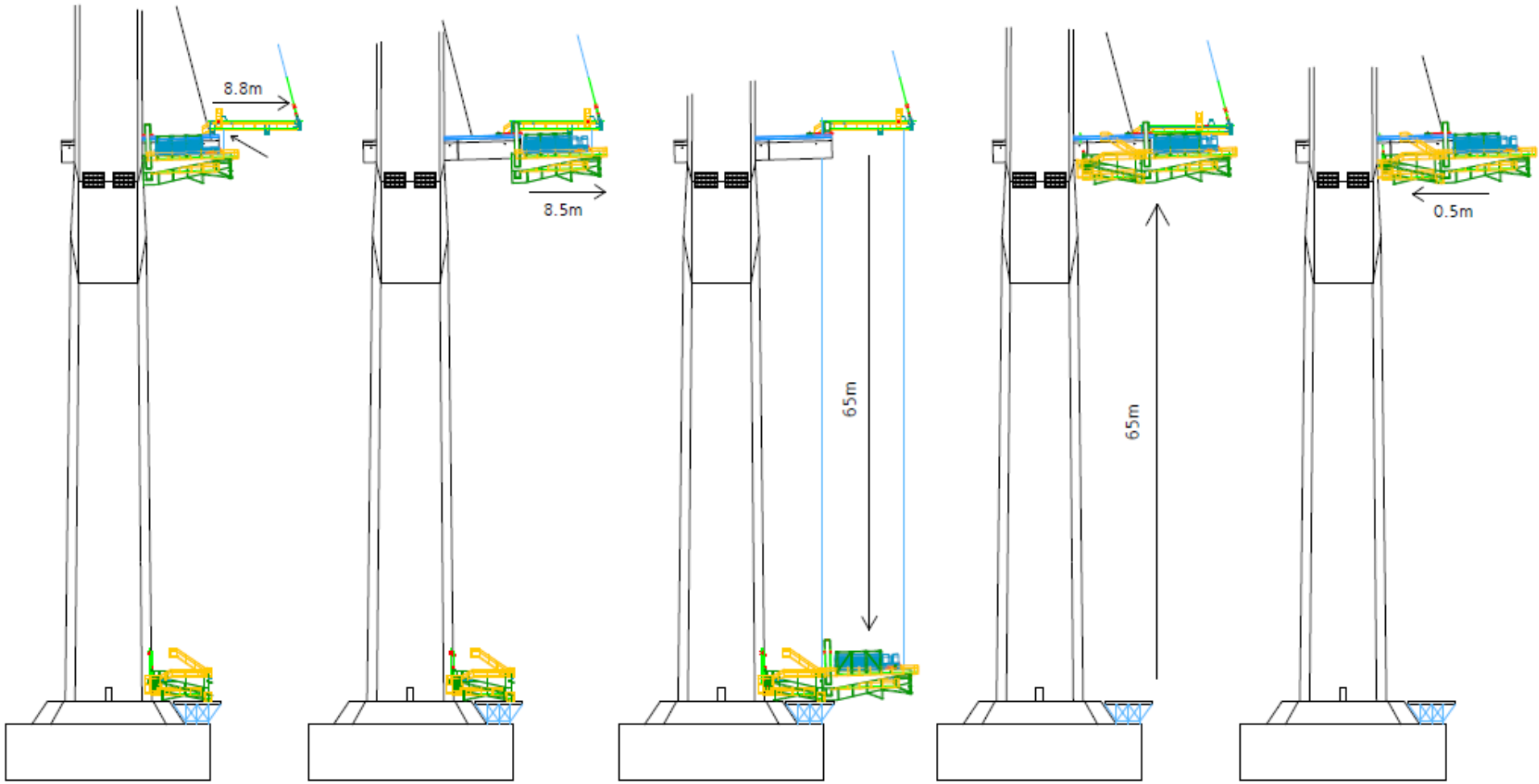


STEP 2:
- PLACE THE RAILS AND LAY THE SKIDDING SHOES OVER THE RAILS
- REMOVE HOISTING CABLES SUSPENDED FROM THE DECK)
- MOVE THE FT 0.7 m BACKWARD TO THE PYLON



STEP 3:
- ONCE TF IS POSITIONED, ANCHOR THE FT TO THE DECK AT THE C FRAME
- CAMBER THE STRUCTURE
- PLACE REINFORCEMENT
- CAST SS01 SEGMENT
- MEANWHILE THE SECOND HALF OF THE FORMORK MAY BE ASSEMBLED ON THE GROUND LEVEL

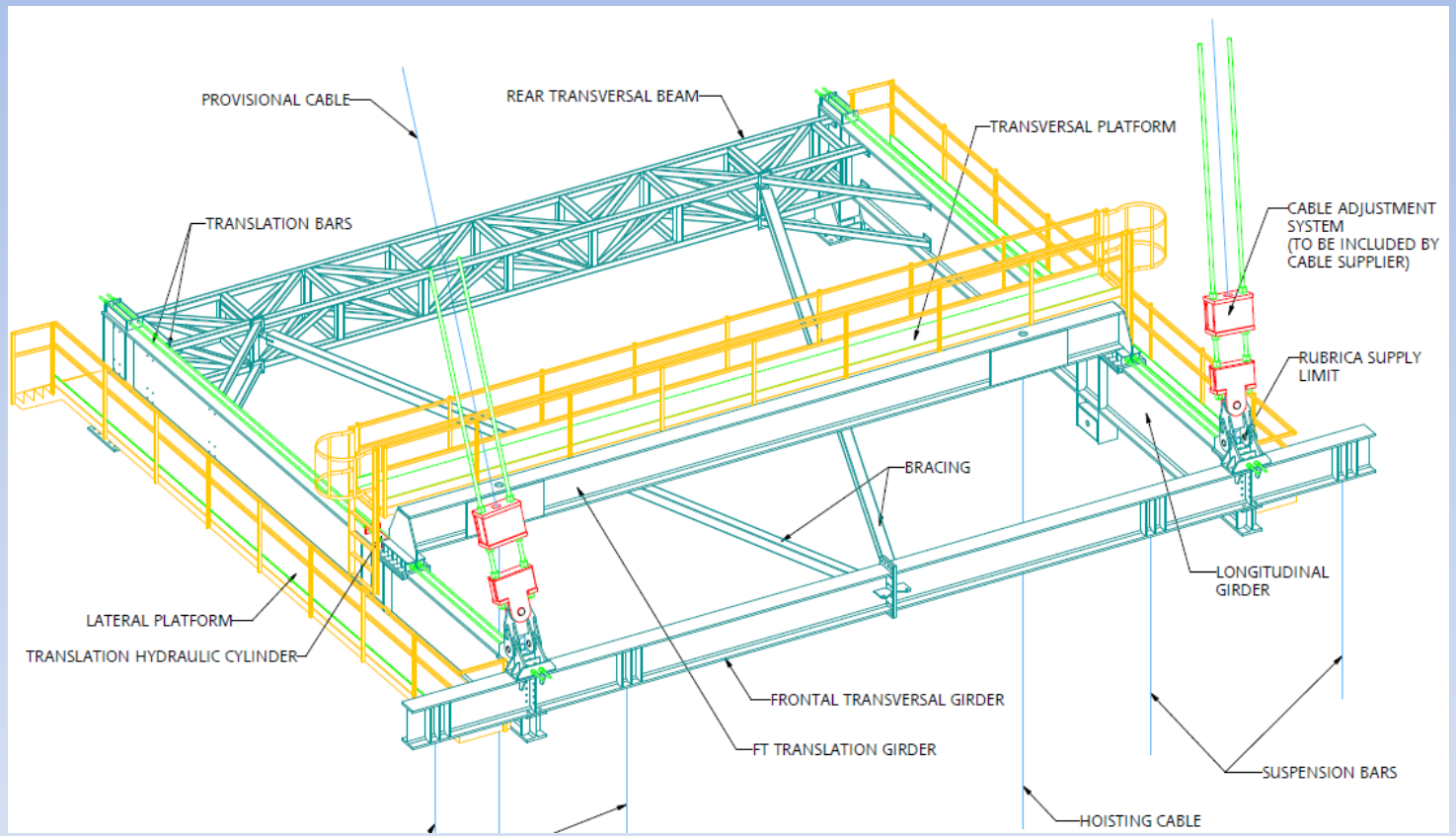
Lifting Sequence (2/2)



- ***Assembly of Front & Rear parts on ground for safety and efficiency***

Lifting Structure

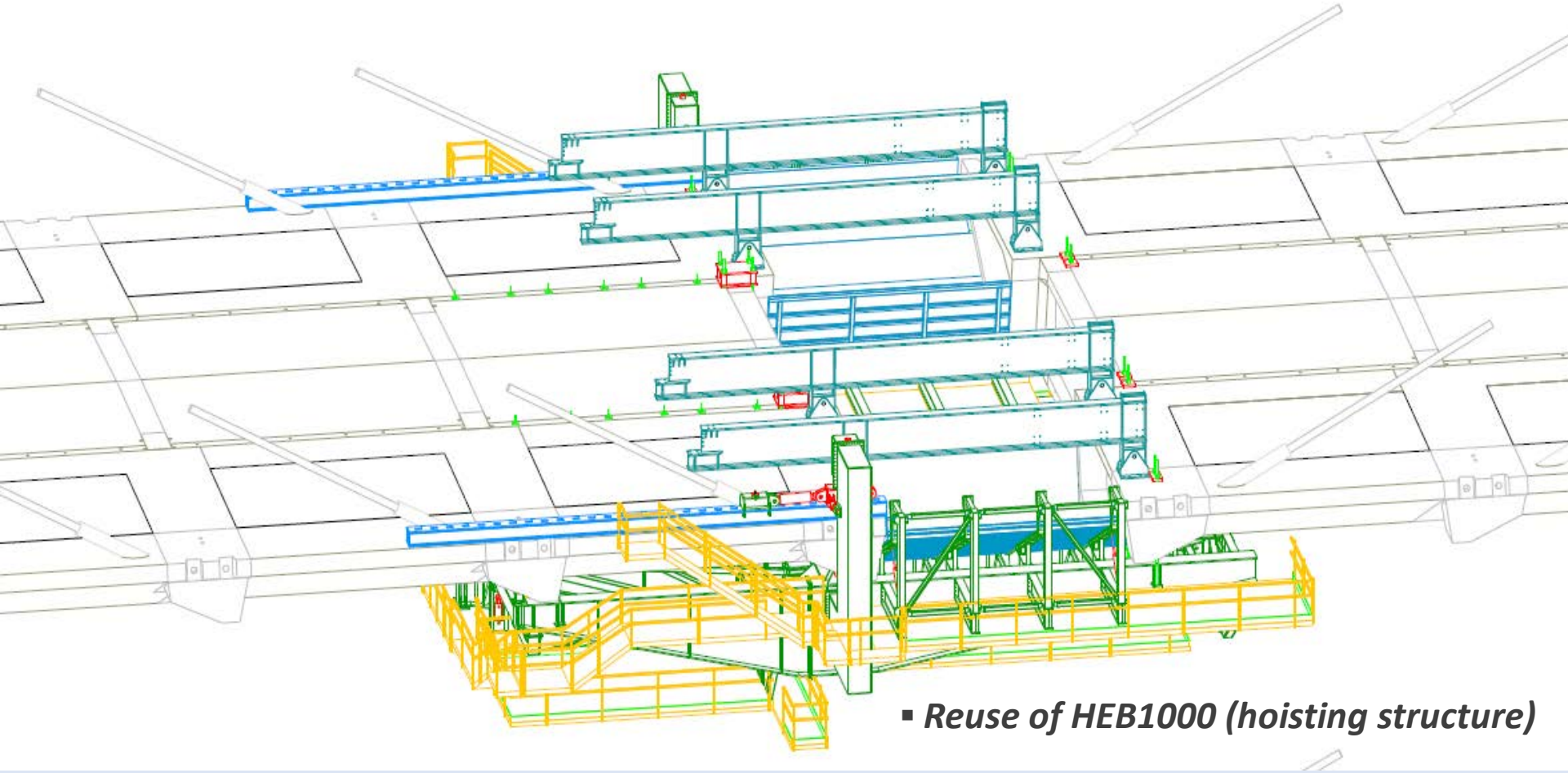
- ***Detail 1 :***



- ***Lifting structure developped by Rúbrica***
- ***Lifting equipment developped by BIM + SARENS***

} ***Coordination by BIM***

Stitching



- ***Reuse of HEB1000 (hoisting structure)***

Puente sobre el Canal en el lado Atlántico

Animación del proceso

Fuente: Autoridad del Canal de Panamá

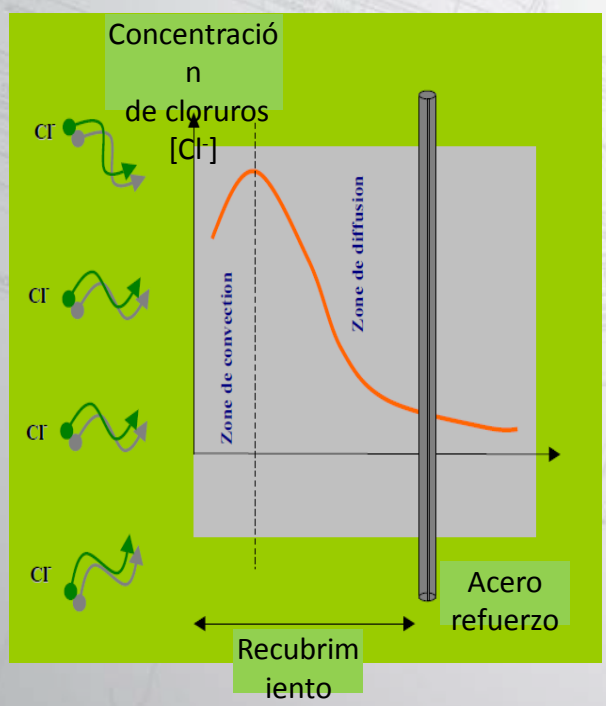
Puente sobre el Canal en el lado Atlántico

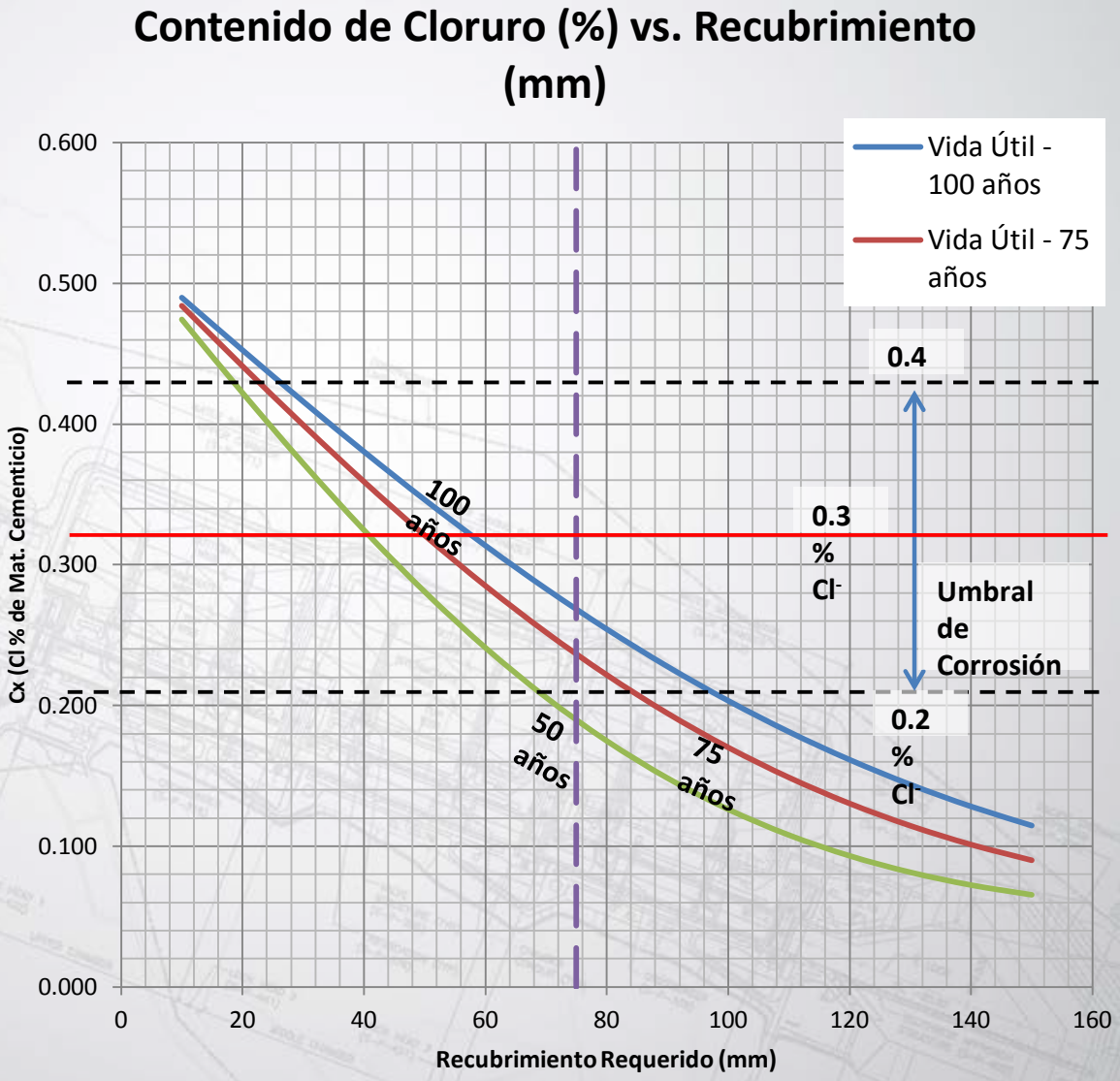
Durabilidad

Fuente: Autoridad del Canal de Panamá

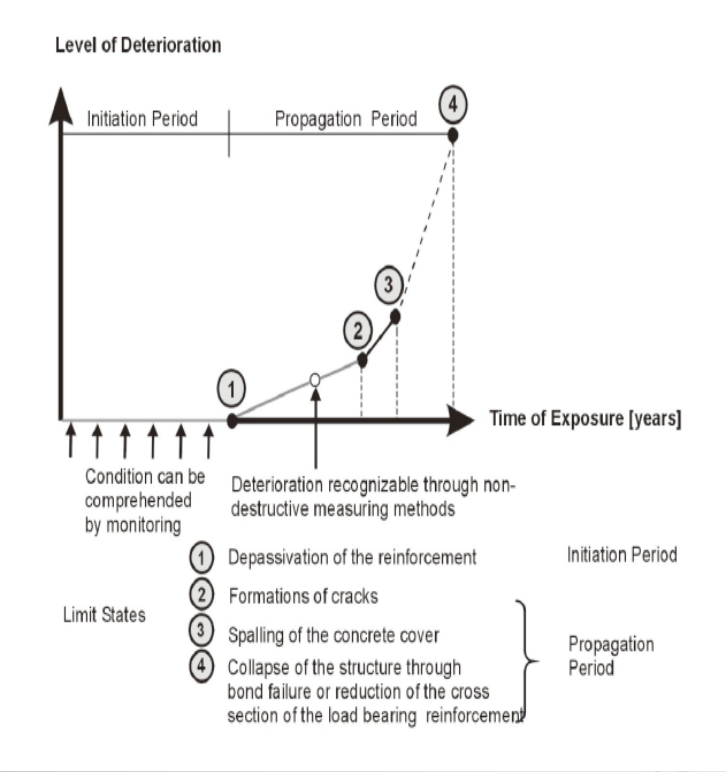
RECUBRIMIENTO

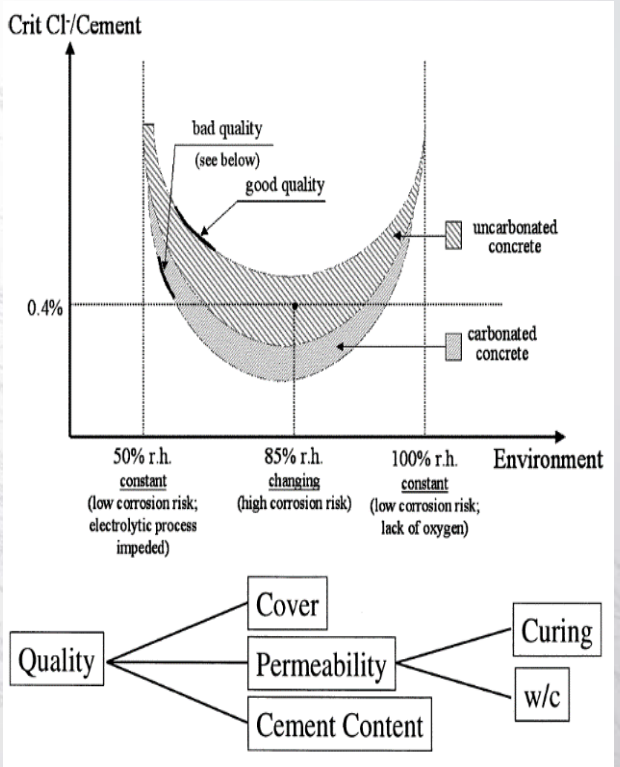
Recubrimiento mínimo depende de muchos factores: Difusión del ión cloruro, umbral de corrosión, vida de servicio esperada, y ambiente o exposición.





RECUBRIMIENTO





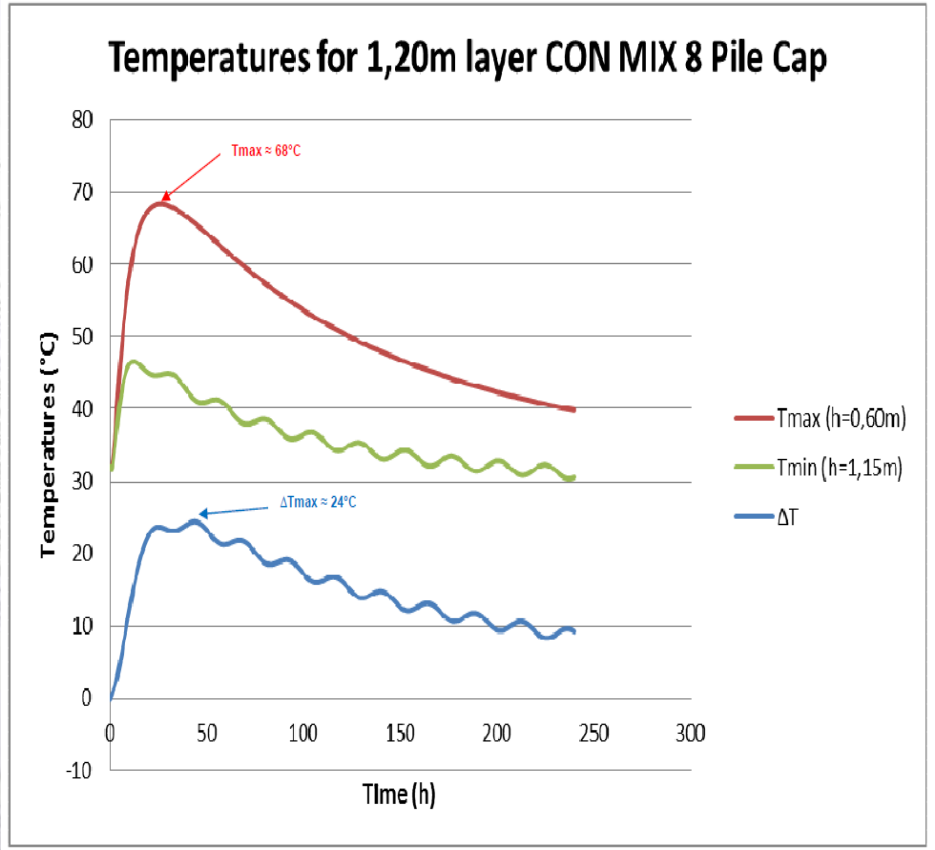
CONTROL DE CALIDAD

Temperatura máxima del hormigón en el punto de vertido deberá ser ≤ 32° C

Para concreto masivo:
Temperatura máxima interna del hormigón deberá ser ≤ 75° C

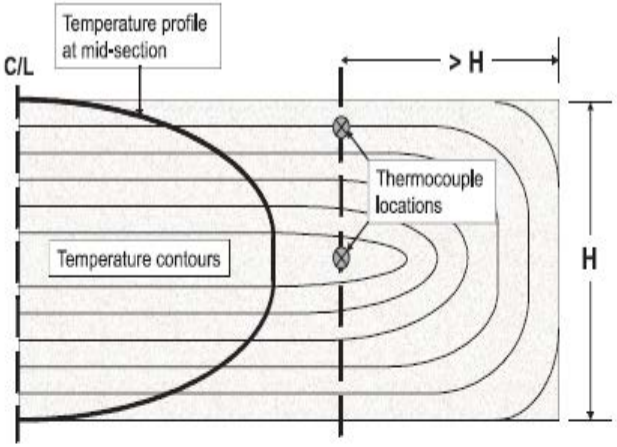
Máximo gradiente de temperatura entre el núcleo y la superficie del hormigón deberá ser ≤ 25° C.

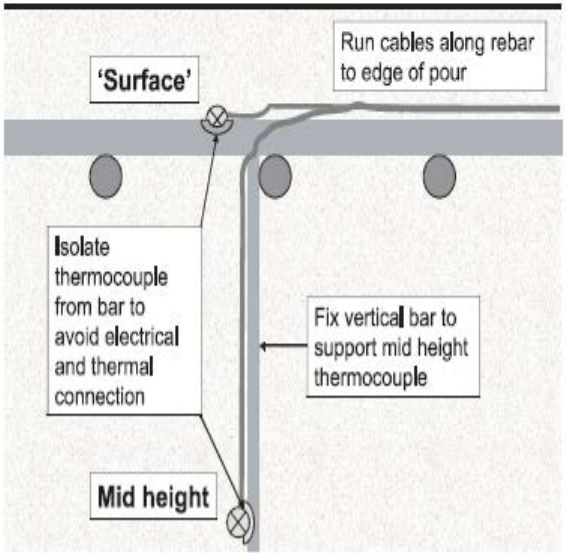
Resultados del modelo térmico para: Temperatura de vertido = 32° C, espesor de capa = 1.20m, mezcla de concreto 8 (relación w/mc=0.37, mc=350+2*20+0.25*50=402.5kg)



Fuente: Submittal 34 90 08-122 Thermal Concrete Study P22/P23 Pile caps – 1st Layer (RPT-GEN-LAB-G-VCS-09700)

CONTROL DE CALIDAD





CONTROL DE CALIDAD

Puente sobre el Canal en el lado Atlántico

Trabajos realizados

Fuente: Autoridad del Canal de Panamá

West Side – Temporary platforms and roads

P23 Island

East Side – Temporary platforms and roads

Osterberg Test P23

Se realizaron 6 ensayos de pilotes de prueba con sistema de celdas osterberg

Progreso de la Construcción – Enero 2015

Facilidades Temporales – Lado Este

Progreso de la Construcción – Enero 2015

Facilidades Temporales – Lado Oeste

Construcción de pilotes

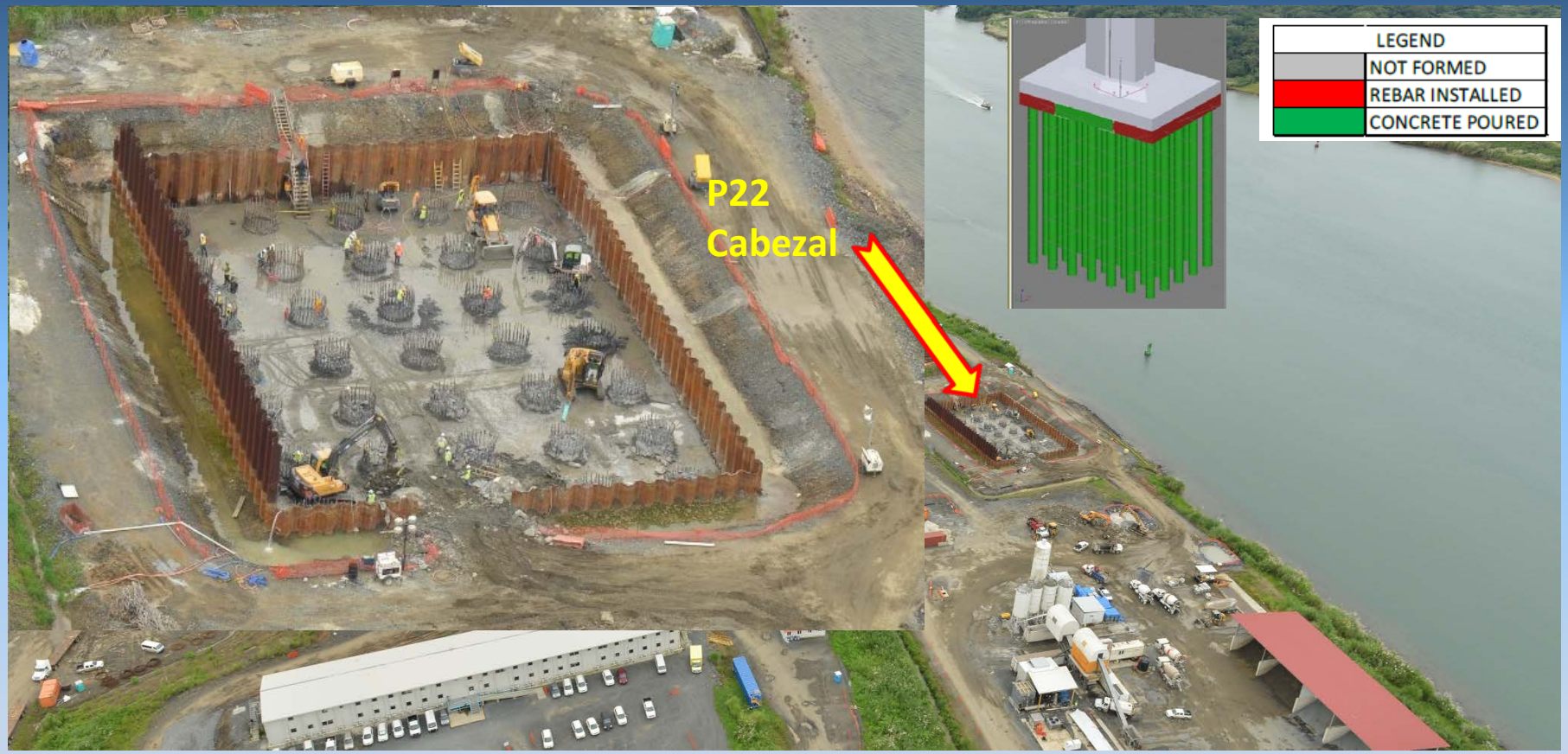
Se han realizado un total de (7.4Km) 249 pilotes de los 382 del proyecto distribuidos así:

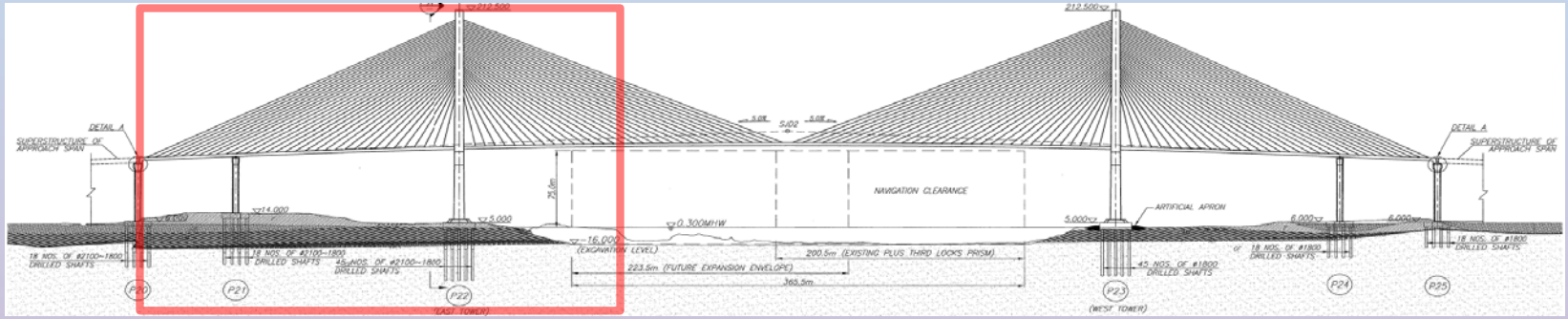
- **Puente Principal: se completaron (5.2Km) 144 pilotes entre las Pilas P20, P21, P22, P23, P24 y P25 los cuales representan el 100% de los pilotes del puente principal atirantado.**

- **Viaducto Oeste: se completaron (2.2Km) los 105 pilotes culminando la totalidad de los pilotes del viaducto oeste, distribuidos entre pilas P26 @ P40 y A41(estribo).**

- **Viaducto Este: se inició la construcción de pilotes en el A1.**

Progreso de la Construcción





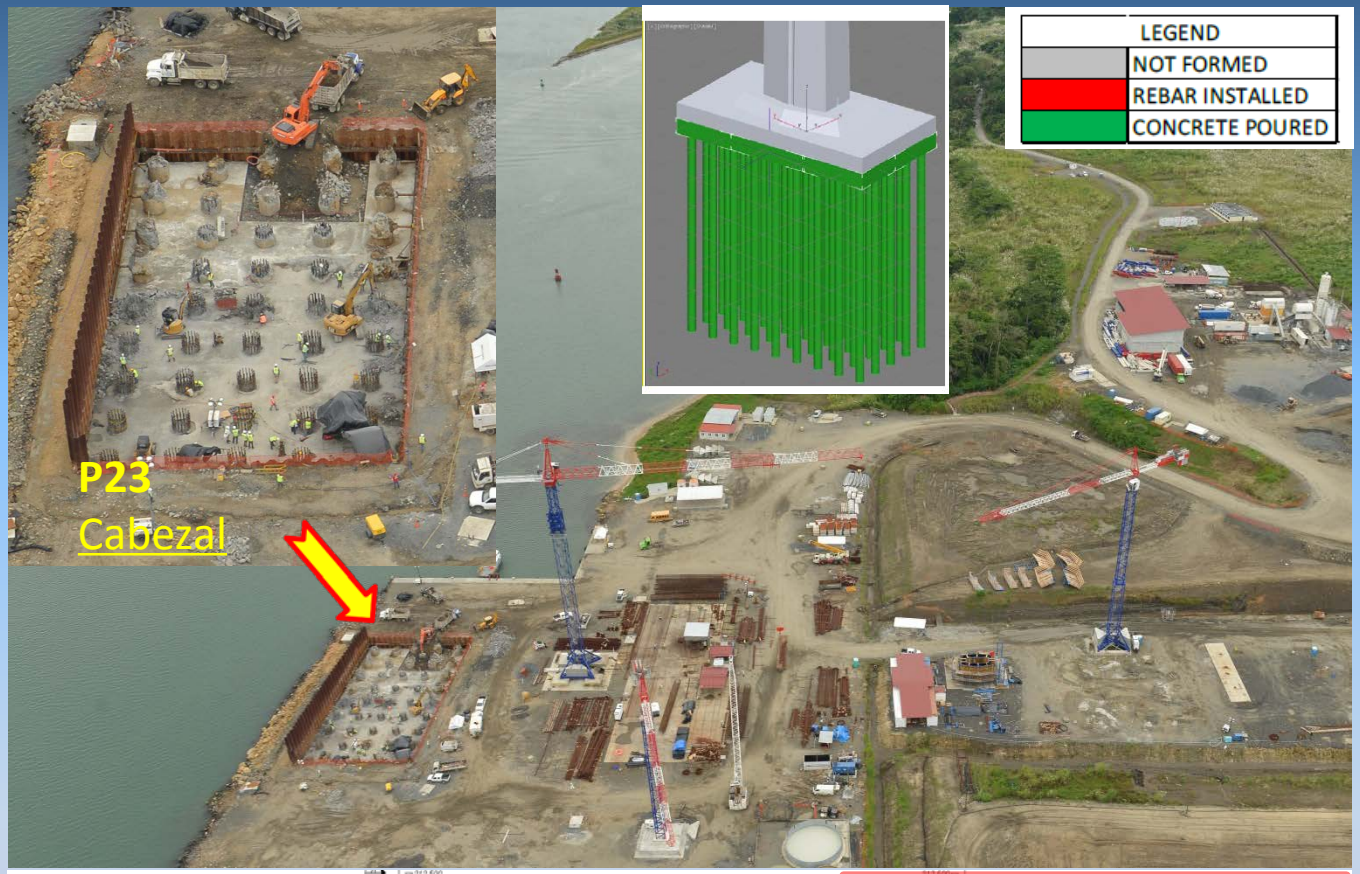
CAT

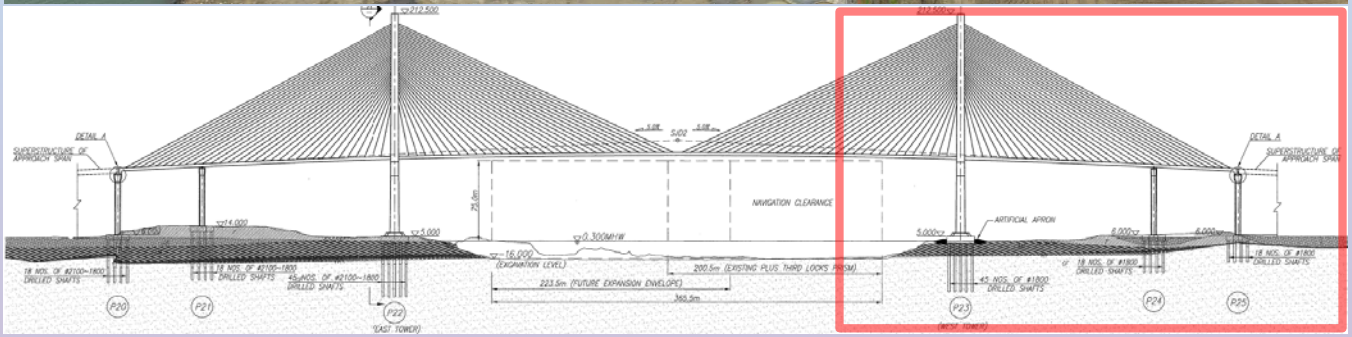
Avances del cabezal de la Pila P22

>8500m3 de concreto (9 bloques)

>1300ton de acero

Progreso de la Construcción





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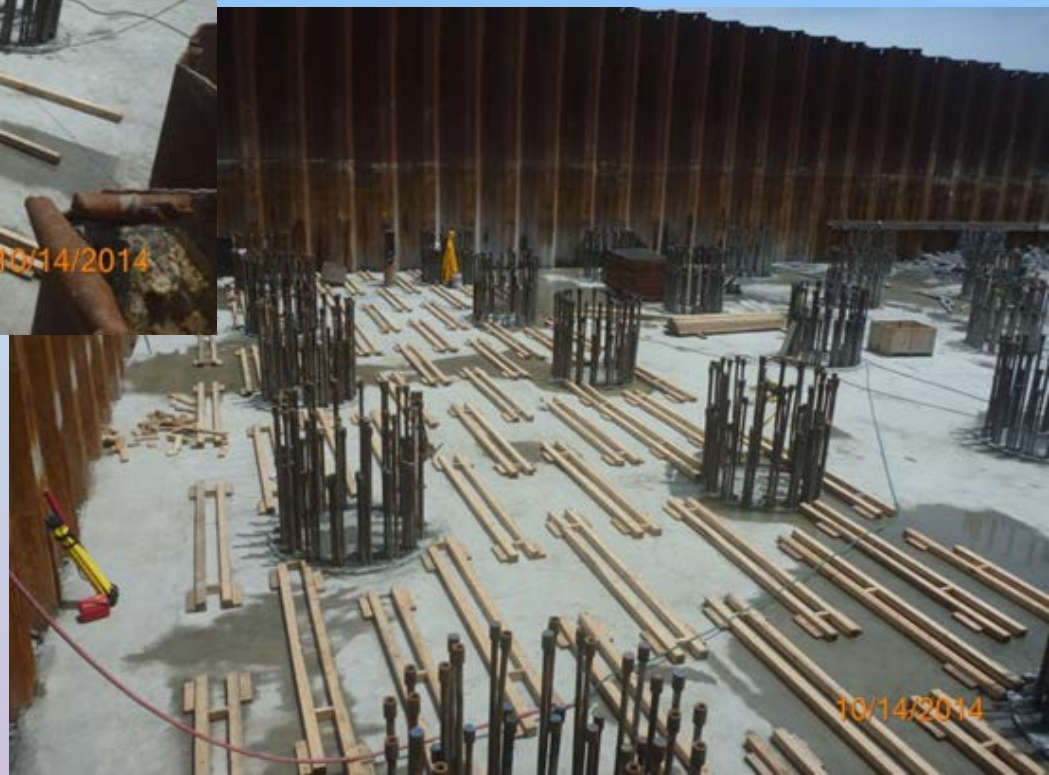
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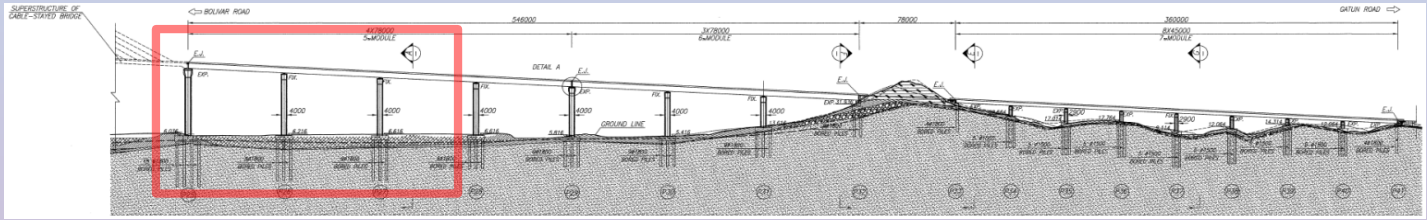
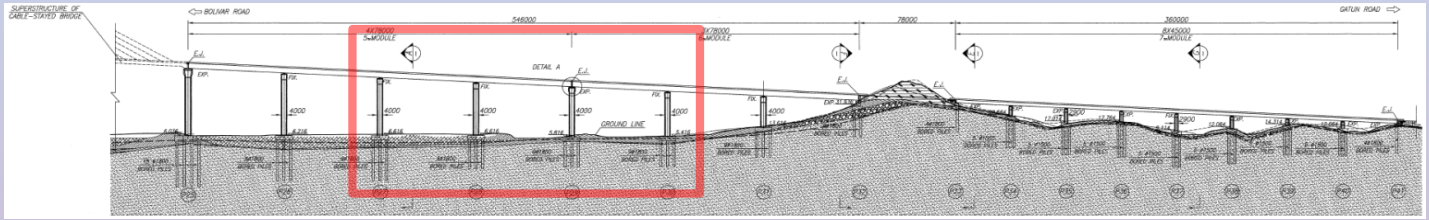
Avances del cabezal de la pila P23

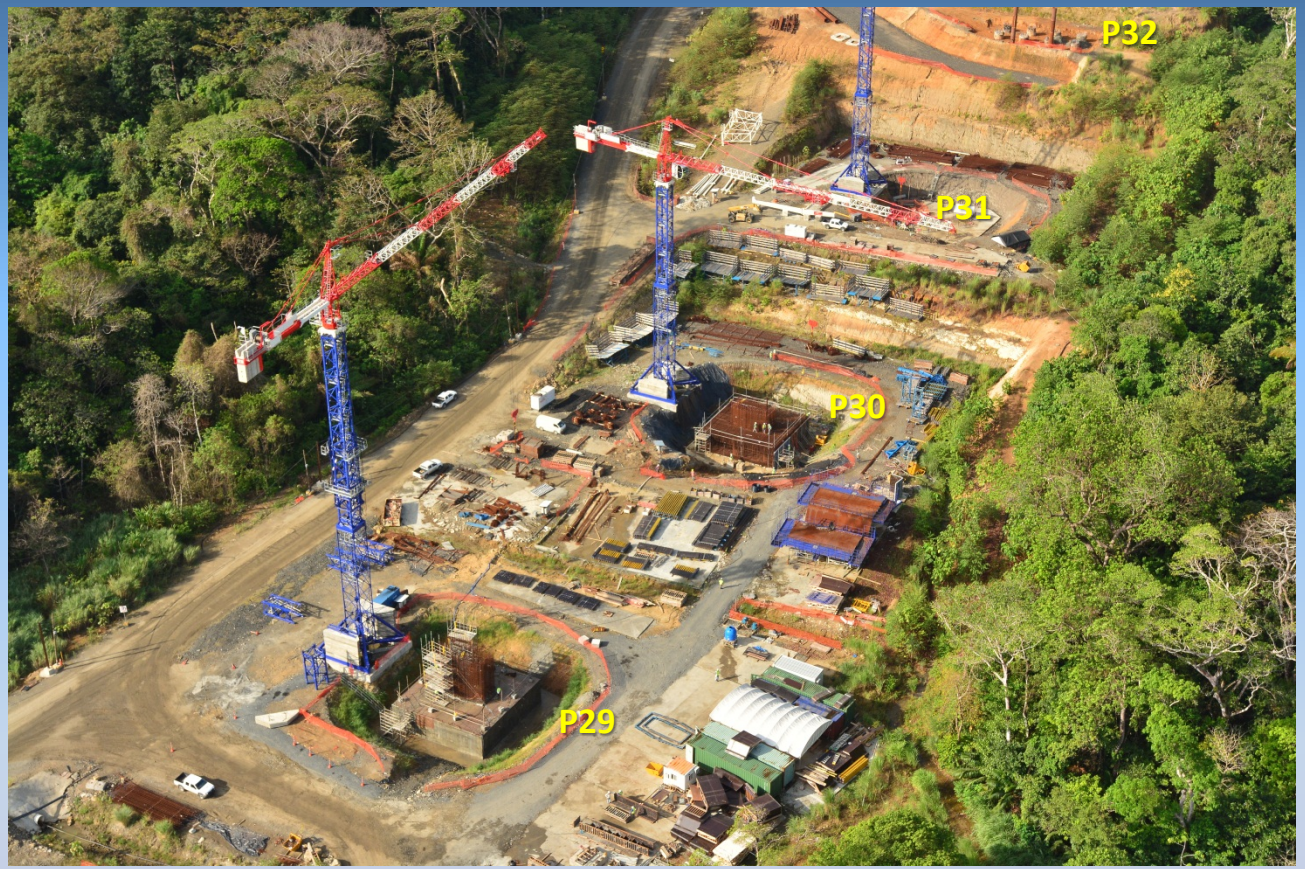
Progreso de la Construcción – Enero 2015

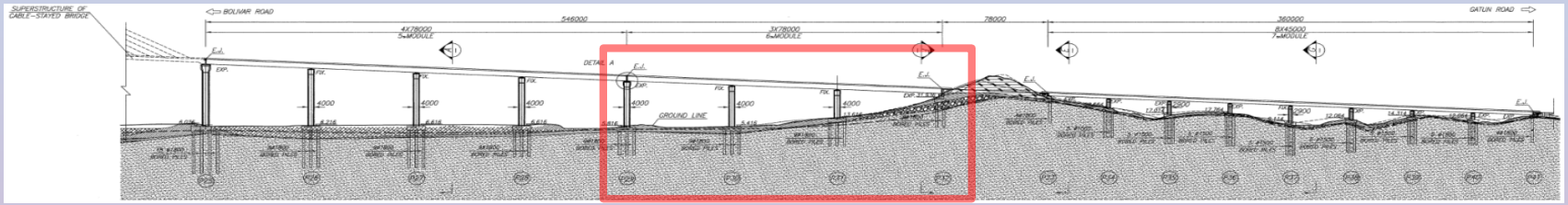


Progreso de la Construcción – Enero 2015

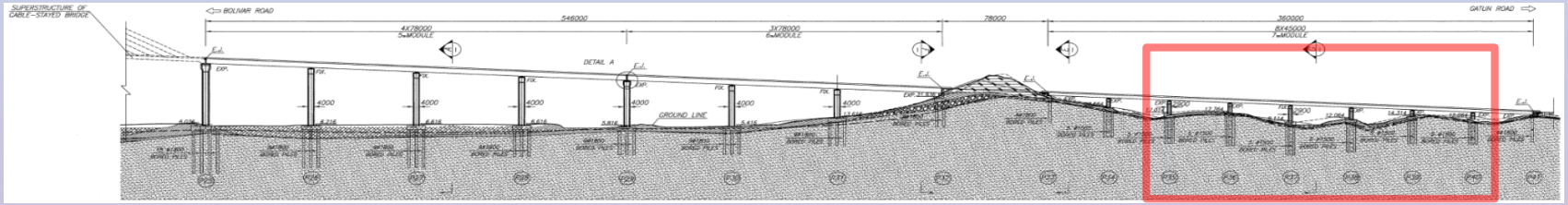


Progreso de la Construcción – Enero 2015

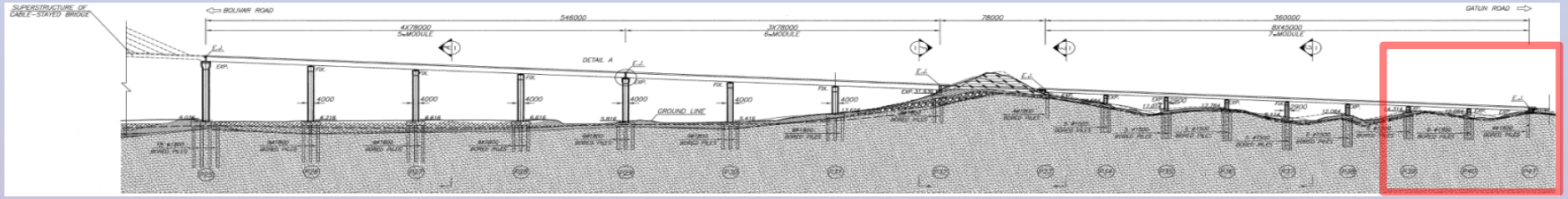




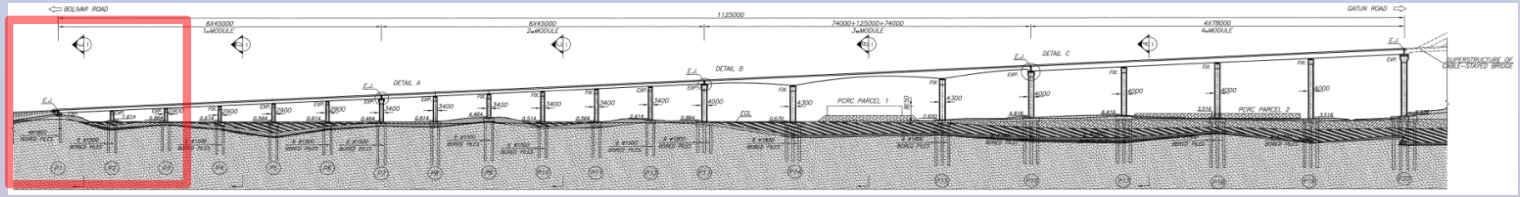
Progreso de la Construcción – Enero 2015



Progreso de la Construcción – Enero 2015



Progreso de la Construcción – Enero 2015



CANAL DE PANAMÁ

Una vez construido

10 de marzo de 2015
Mario Montemayor
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