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Puentes Bataan–Cavite y Samuel De Champlain: Dos casos de estudio sobre el diseño y construcción de puentes emblemáticos

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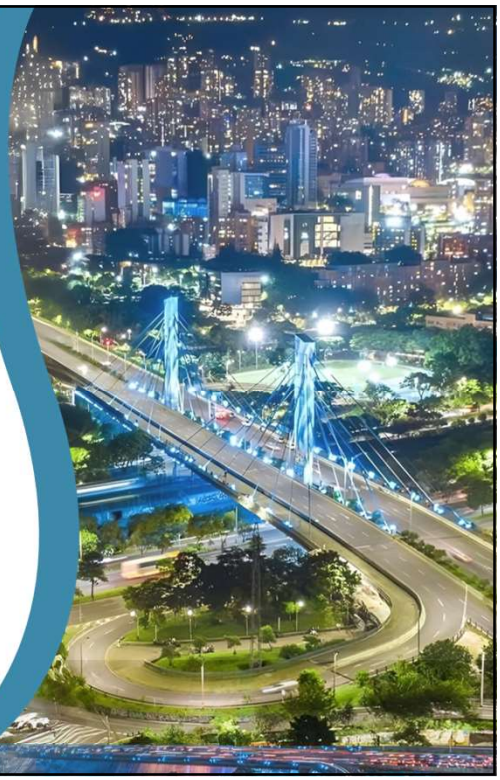

Asociación de Ingenieros Estructurales de Antioquia

SIMPOSIO INTERNACIONAL DE INGENIERÍA DE PUENTES
SIIP 2025

Visión general del proyecto — Área Metropolitana de Manila

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SIMPOSIO INTERNACIONAL DE INGENIERÍA DE PUENTES SIIP 2025 — Asociación de Ingenieros Estructurales de Antioquia

De Medellín para el mundo: Conectando saberes, construyendo futuro

Proyecto Bataan-Cavite Interlink Bridge

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Objetivos del Proyecto:

- Reducir el tiempo de viaje de 4–5 horas a 45 minutos.
- Conectar la masa continental de Bataan, al norte del Área Metropolitana de Manila, con Cavite, al sur del Área Metropolitana de Manila.
- Impulsar el crecimiento económico en ambas regiones.
- Habilitar el desarrollo de los puertos marítimos de Cavite y Bataan como principal puerta de acceso marítimo internacional a Filipinas.
- Proyecto emblemático del Programa de Infraestructura “Build Better More” (BBM).

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Proyecto Bataan-Cavite Interlink Bridge

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SECCIÓN TRANSVERSAL

Descripción del proyecto:

- **Longitud total:** 32.15 km.
- **Tipología:** Segundo puente **atirantado** más largo del Sudeste Asiático; y uno de los 10 vanos más largos de puentes atirantados en el mundo (vano principal de **900 m**).
- **Capacidad vial: 4 carriles** (2 por sentido) **con hombros/acotamientos**.
- **Extremo norte (cabecera norte): Mariveles, Bataan**.

Aspectos clave

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- Vida de diseño: 100 años.
- Puesta en servicio (apertura al tráfico): ~2031.
- Inversión estimada: PHP 219.3 mil millones (≈ USD 3.9 mil millones)
- Propósito: Proveer una solución de puente segura y eficiente que refleje los valores y las características únicas de Filipinas y de su gente.

El proyecto está segmentado en paquetes de contratación

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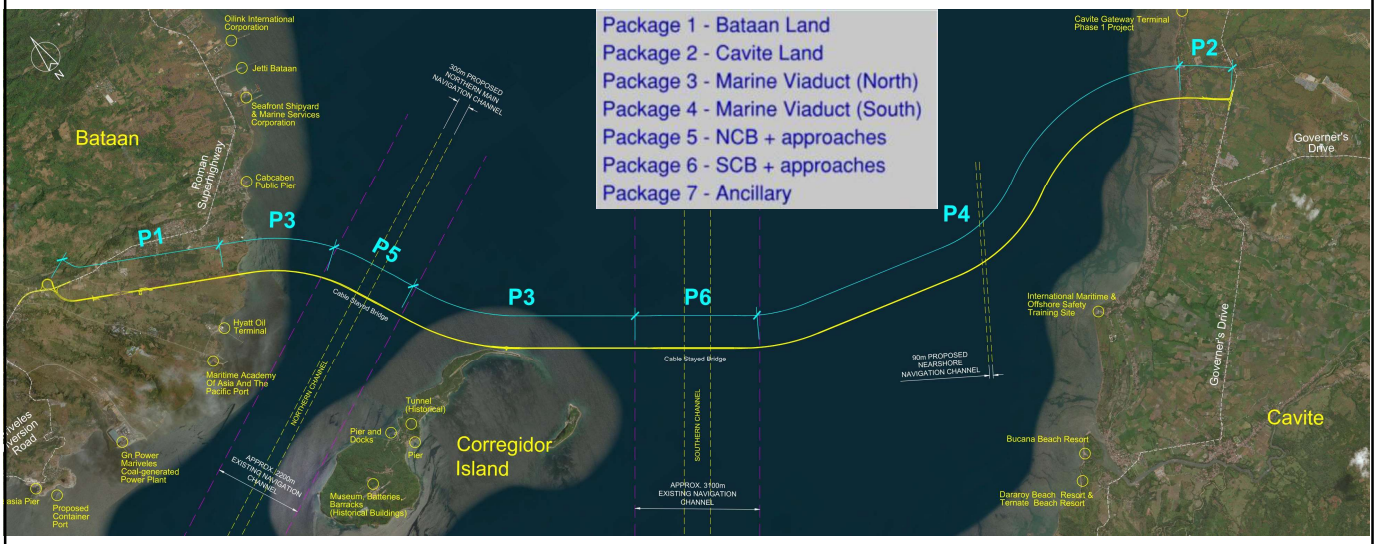

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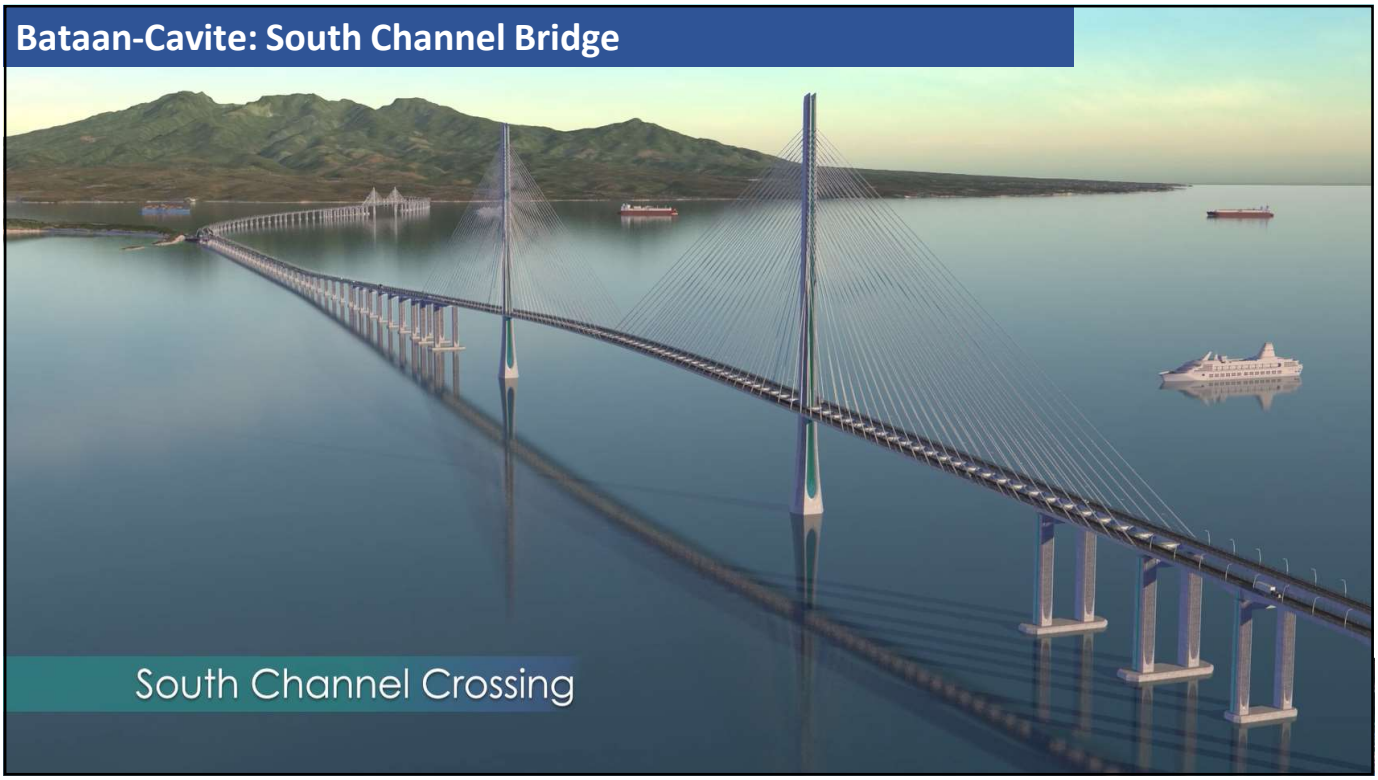
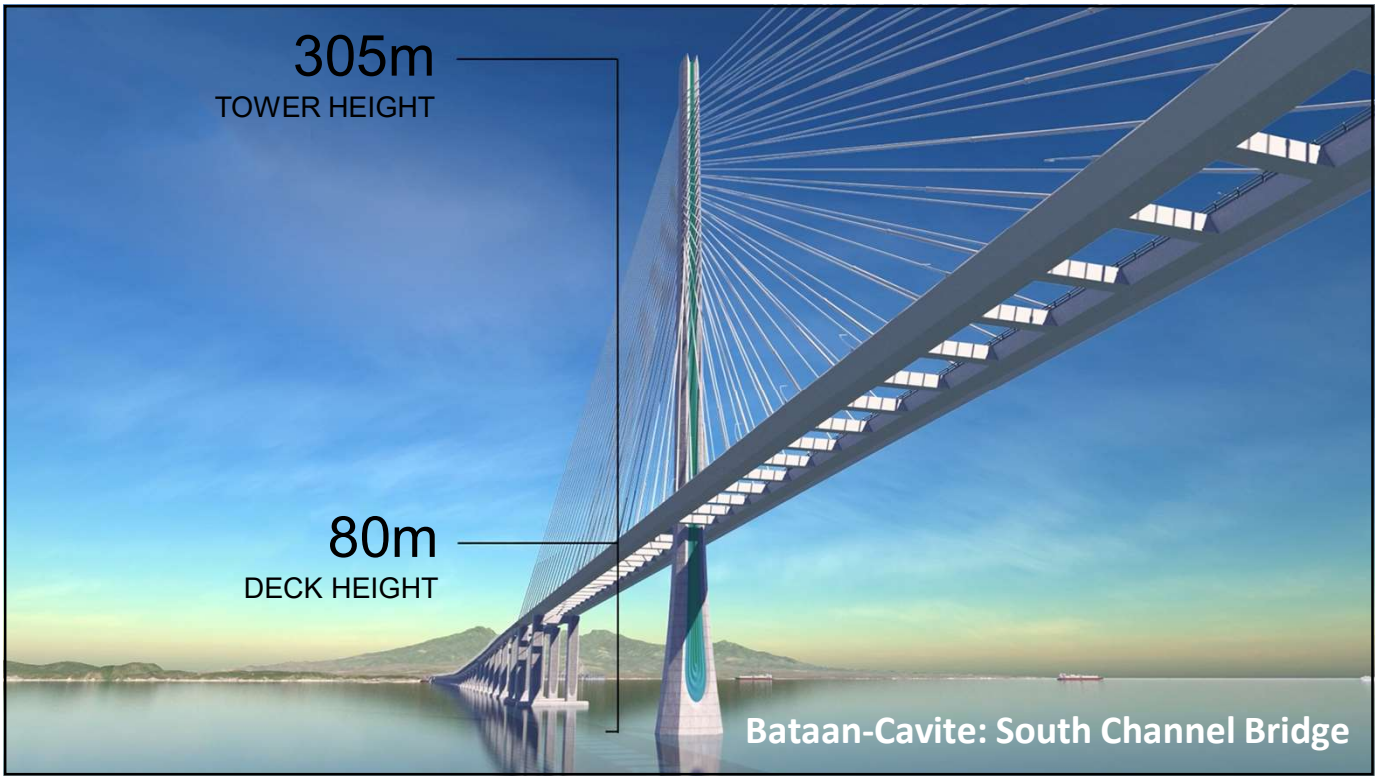
Asociación de Ingenieros Estructurales de Antioquia

De Medellín para el mundo: Conectando saberes, construyendo futuro

Bataan-Cavite: South Channel Bridge




Bataan-Cavite: South Channel Bridge
900m
SPAN


305m
TOWER HEIGHT
80m
DECK HEIGHT
Bataan-Cavite: South Channel Bridge

South Channel Bridge

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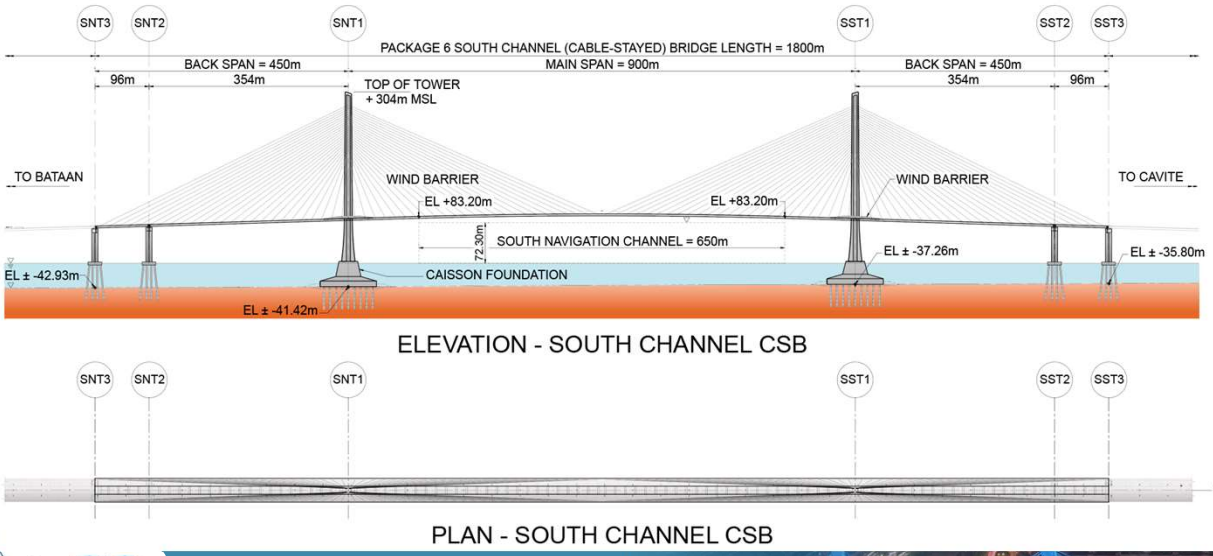

ELEVATION - SOUTH CHANNEL CSB

PLAN - SOUTH CHANNEL CSB

Typical Deck Section - Orthotopic Deck

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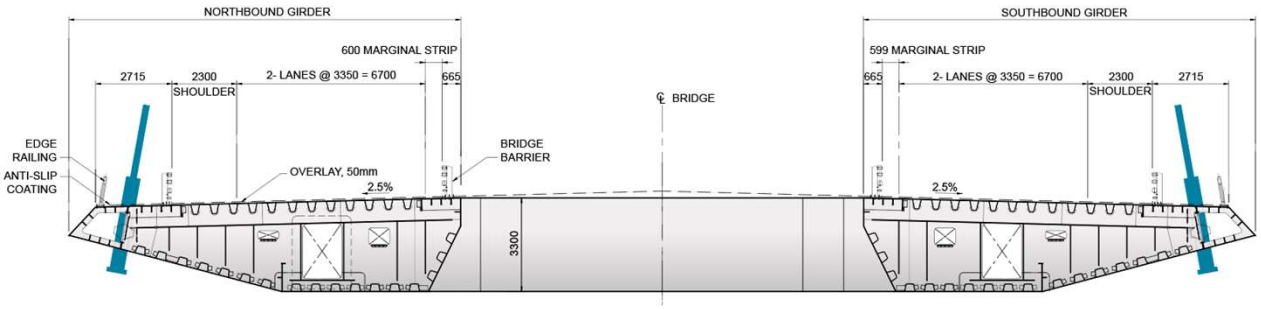

Tower Caisson – Dry Dock Construction

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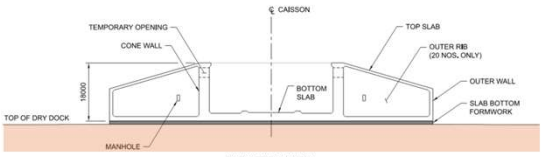
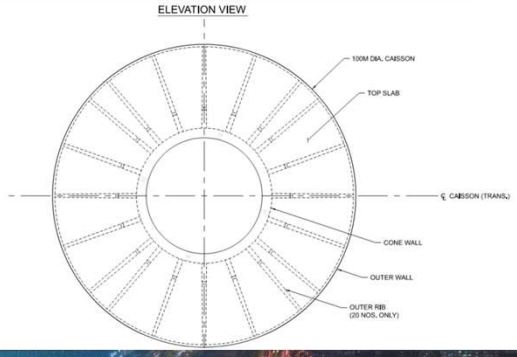
Caisson Construction

STEP 1. INSTALL THE FALSEWORK FOR CAISSON BOTTOM SLAB.

STEP 2. INSTALL THE REBAR CAGES FOR BOTTOM SLAB, OUTER RIBS, OUTER WALL AND CONE WALL.

STEP 3. CAST IN PLACE THE BOTTOM SLAB WITH OUTER WALL, CONE WALL, 20 NOS. OUTER RIBSAS SHOWN WITH TOP SLAB.





Tower Caisson – Dry Dock Construction

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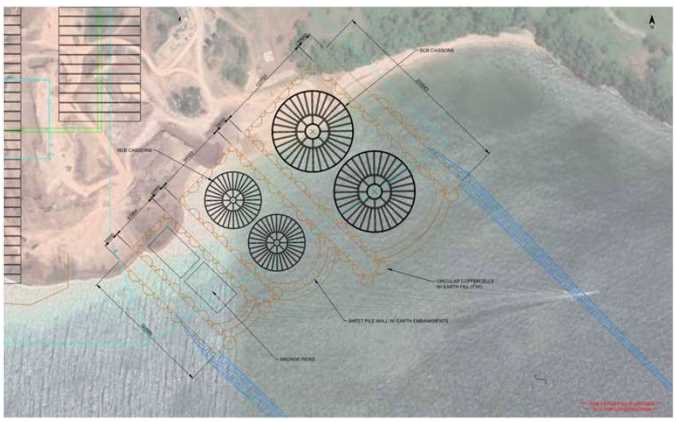
Caisson Construction



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Tower Caisson – Wet Dock Construction

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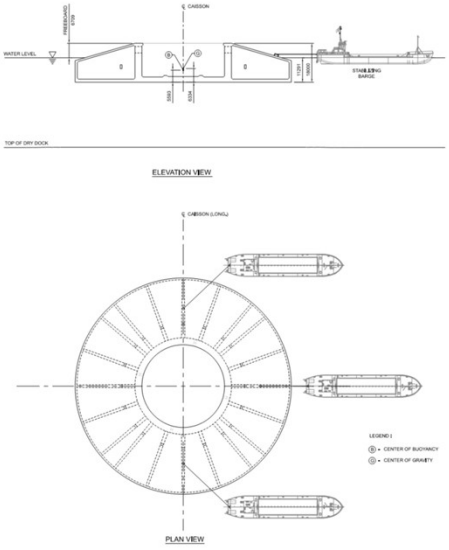
Caisson Float-out to Wet Dock


Rion-Antirion Bridge



Tower Caisson – Wet Dock Construction

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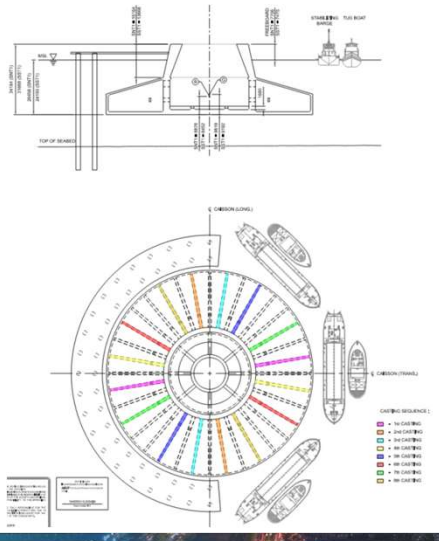
Caisson Construction at Wet Dock


Rion-Antirion Bridge



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Tower Caisson Erection– Site Preparation

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Seabed Dredging

Rion-Antirion Bridge

Inclusion Pile Driving to reinforce seabed

Rion-Antirion Bridge

Tower Caisson – Erection @ Site

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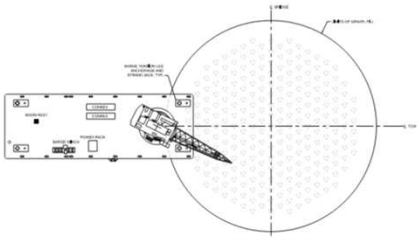
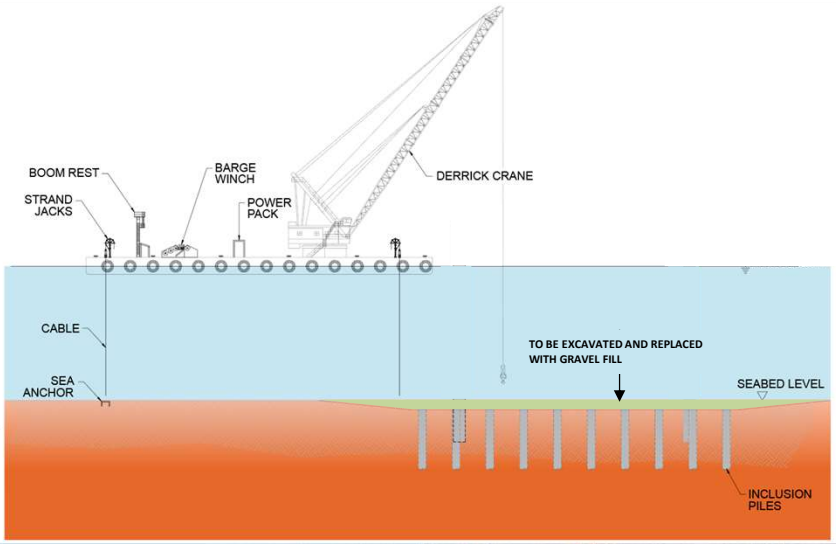
Caisson Erection

Step 1: Excavate the top of seabed soil and prepare pile template

Step 2: Drive and Install all inclusion piles

Step 3: Place the Gravel Fill





Tower Caisson - Construction

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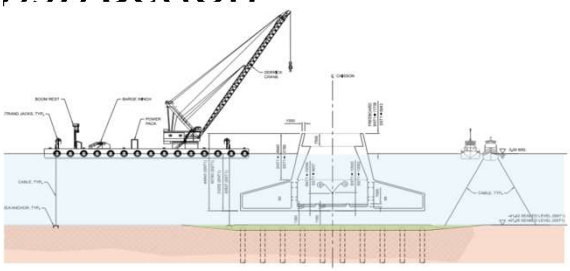
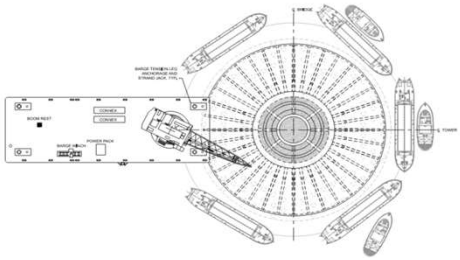
Caisson Erection

Step 4: Float the pre-fabricated caisson in place

Step 5: Stabilize Caisson using stabilizing barges and tugboats





Tower Caisson - Construction

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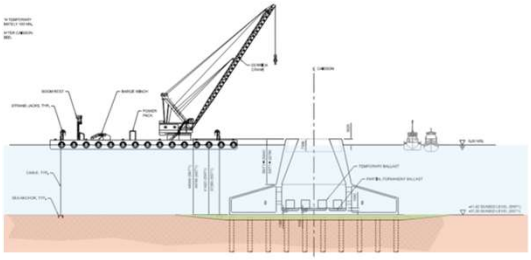
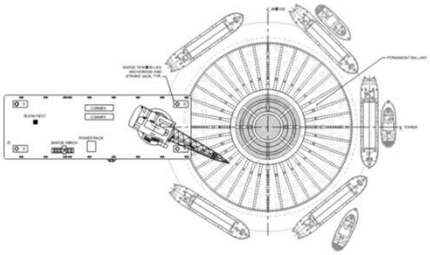
Caisson Erection

Step 6: Sink Caisson to bottom of seabed with temporary ballast weight as needed to sink the caisson until it lands at top of gravel

Step 7: Cast the remaining upper cone wall after caisson landing at seabed.





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Tower Caisson - Foundation

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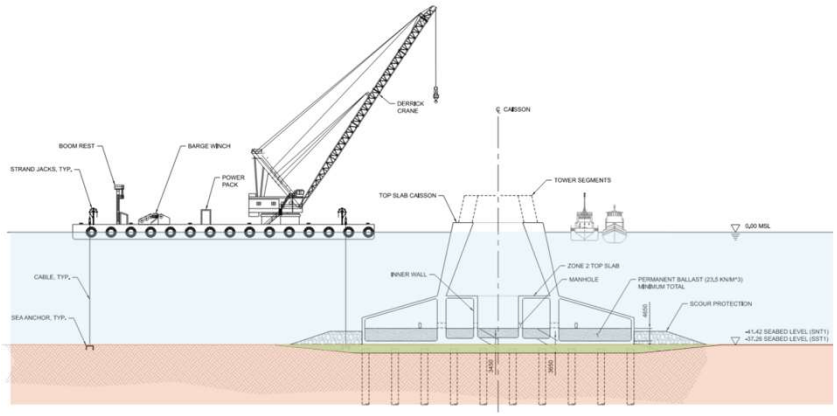
Caisson Erection

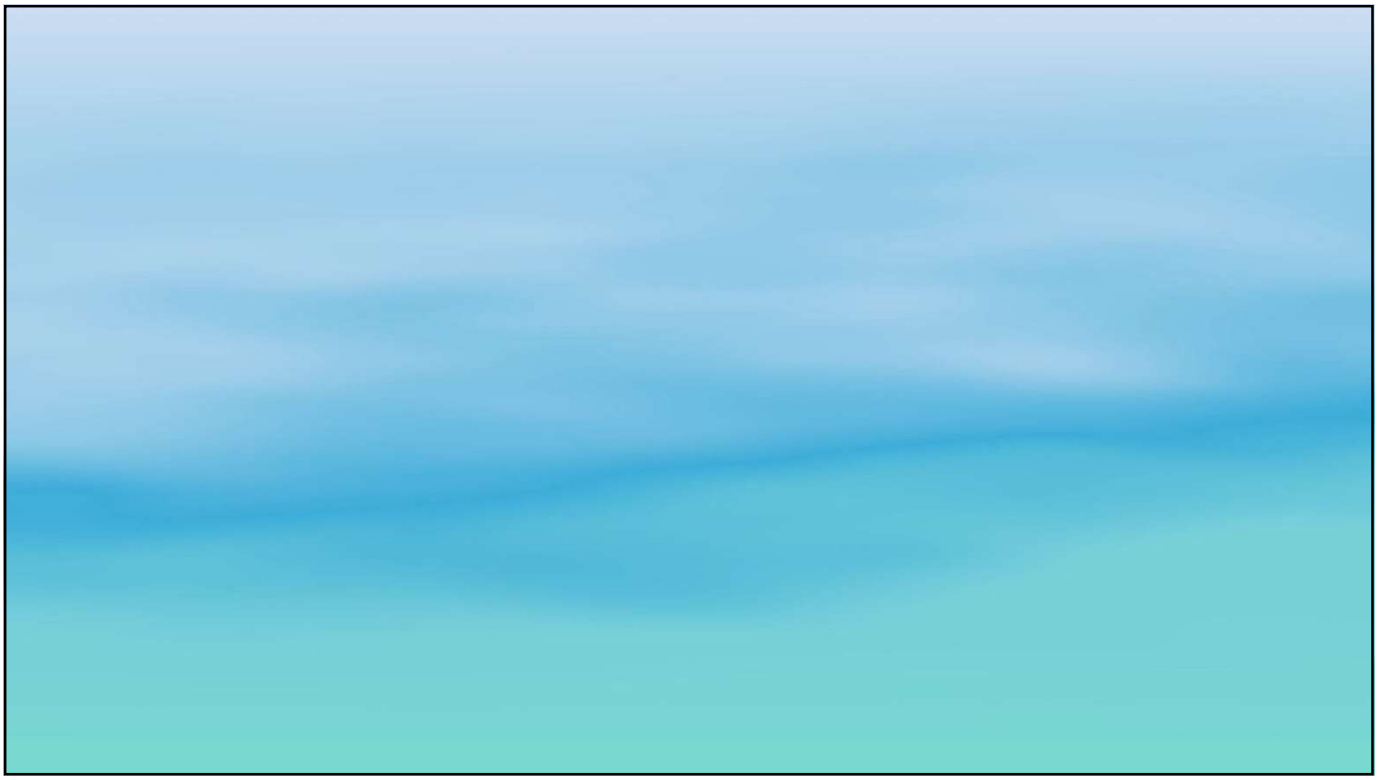
Step 8: Cast the remaining inner ribs and inner walls

Step 9: Remove temporary ballast and place perm permanent ballast per design

Step 10: Install scour protection

Step 11: Proceed with tower segment erection





SCB Tower Erection

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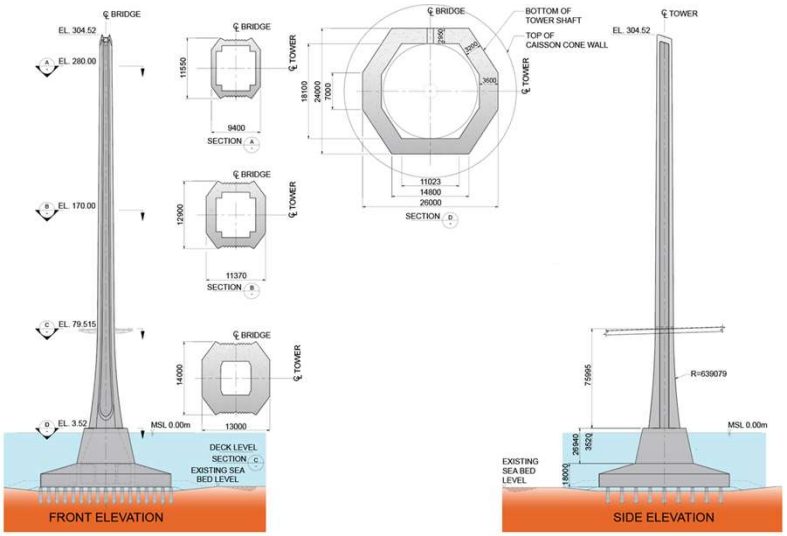

SCB Superstructure Fabrication

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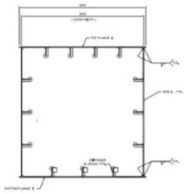
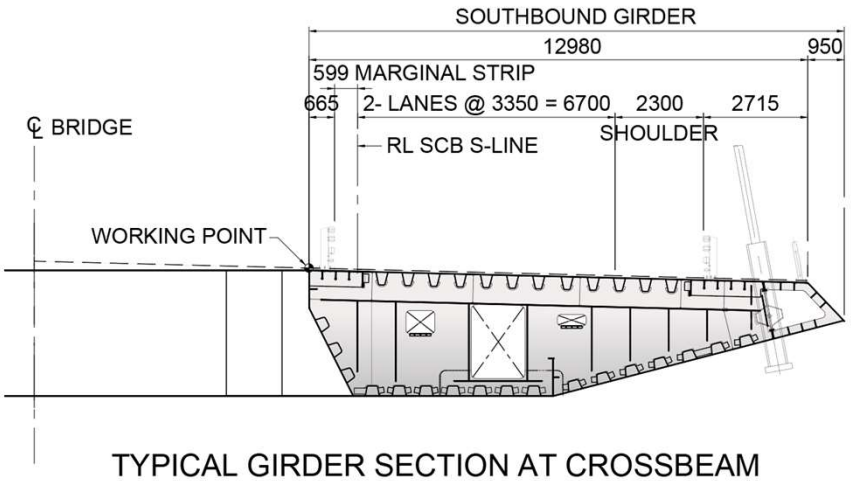
Orthotropic Box Girder (OBG) – Typical Segment Fabrication

Cross Beam Section





SCB Superstructure Fabrication

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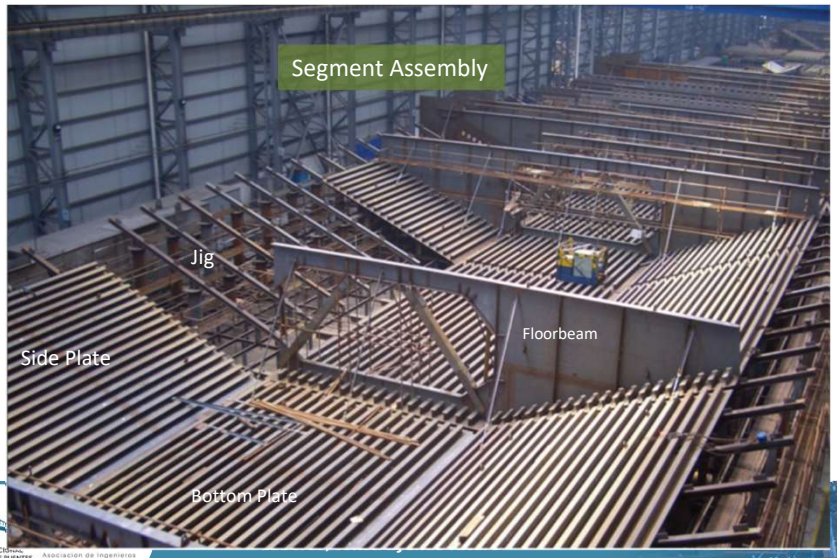
Orthotropic Box Girder (OBG) – Typical Segment Fabrication



Parts & Subassemblies

Setting up jigs

SCB Superstructure Erection

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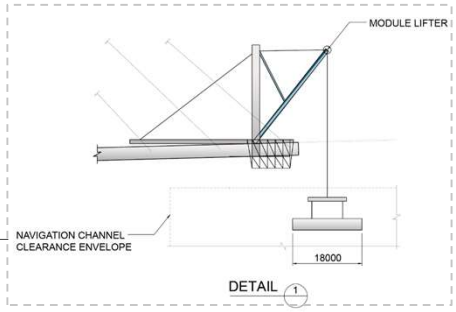

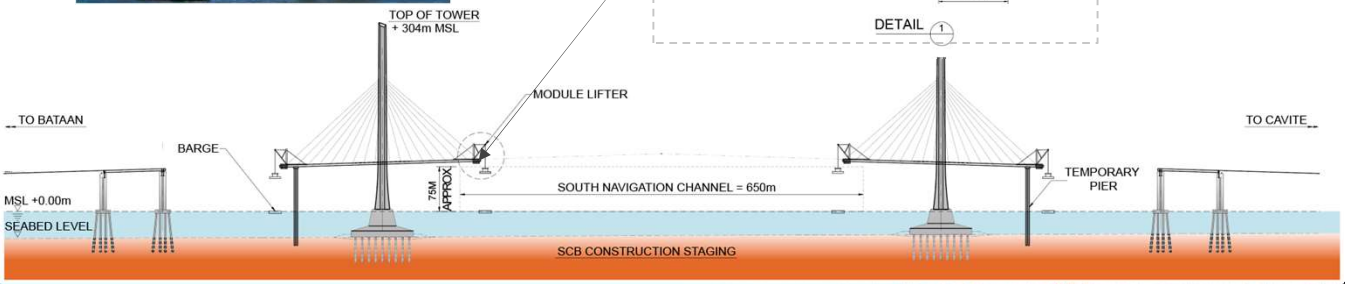

SCB Superstructure Erection

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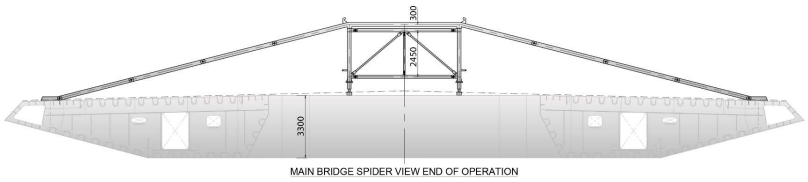
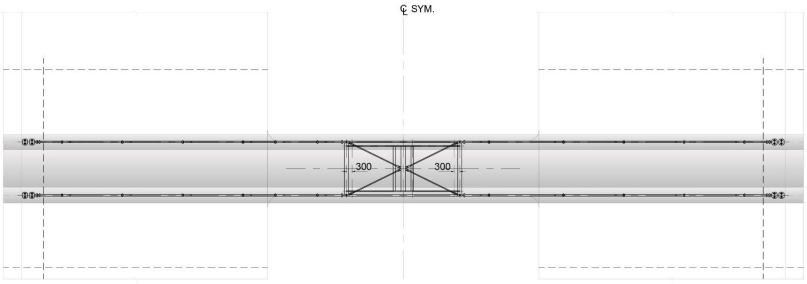


MAIN BRIDGE SPIDER VIEW END OF OPERATION



MAIN BRIDGE SPIDER PLAN VIEW

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North Channel Bridge (NCB)

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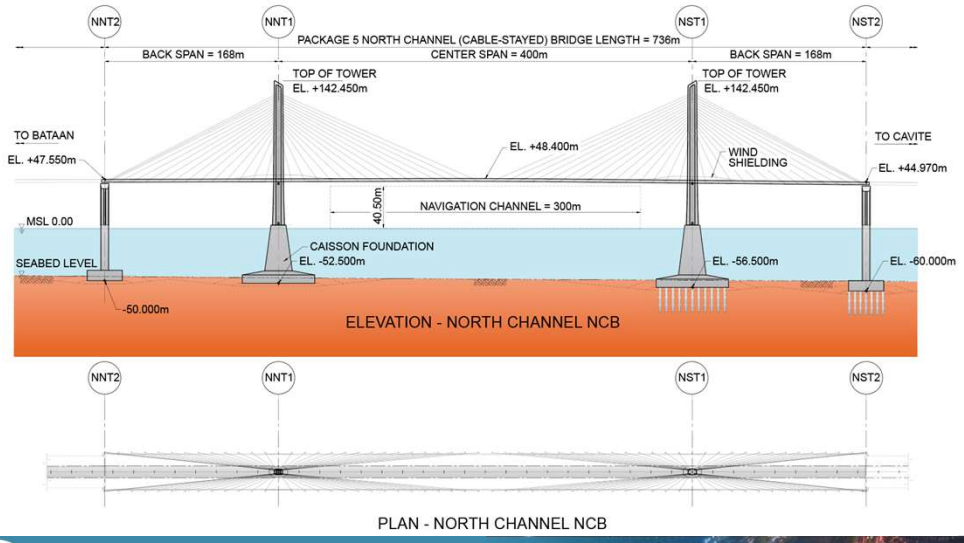

PLAN - NORTH CHANNEL NCB

Typical Deck Section: Composite Deck

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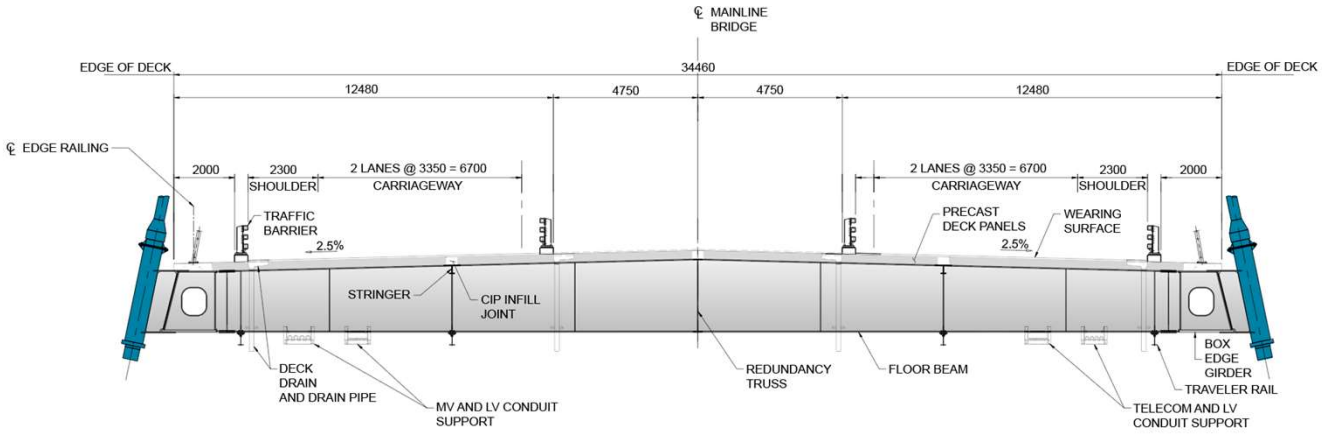

TYPICAL DECK SECTION

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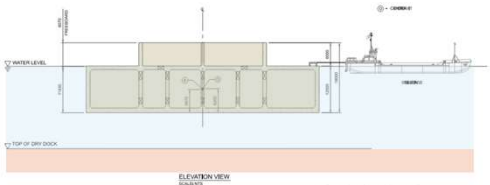
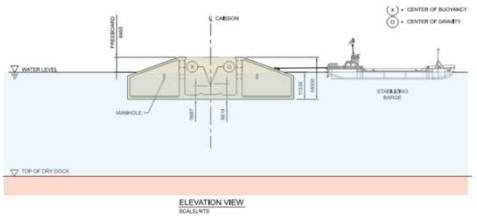
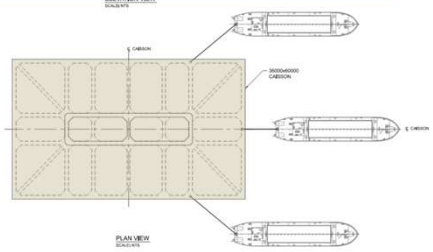
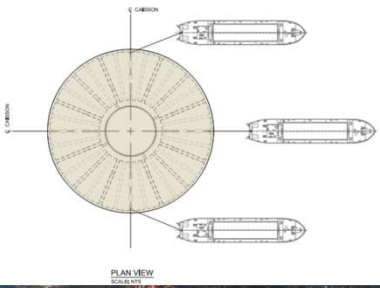
Tower & Anchor Pier Caissons – Dry/Wet Dock Construction

Similar to South Channel Bridge









Anchor Pier Caisson

Tower Caisson

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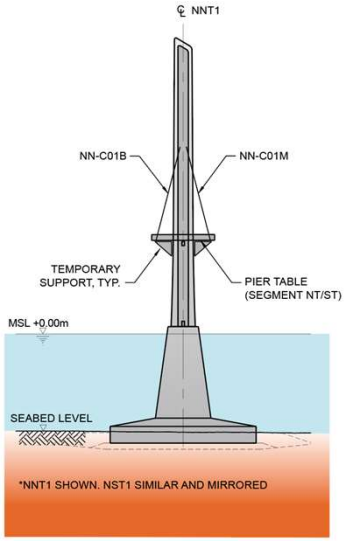
Superstructure Erection



Stage 1

1. Construct foundations, towers, and anchor piers
2. Place Pier Table (segment NT/ST) on Temporary Supports
3. Engage Transverse/Longitudinal Restraints
4. Install Cables NN-C01B/NN-C01M
5. Cast Pier Table (segment NT/ST) Deck Concrete
6. Adjust cables NN-C01B/NN-C01M
7. Remove temporary supports

Port Mann Bridge

Superstructure erection

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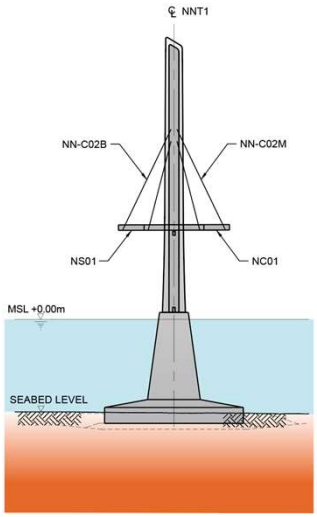

Stage 2

1. Erect Module Lifer and erect field segment NS01 steel with spider frame
2. Install cables NN-CO2B and stress to initial load
3. Place NS01 Deck Panels
4. Tune/adjust cables NN-C02B
5. Pour NS01 Longitudinal and Transverse CIP joint between deck panels and along edge girde
6. Adjust cables NN-C02B
7. Erect NC01 similar to NS01 sequence steps 1 thru 6

Superstructure erection

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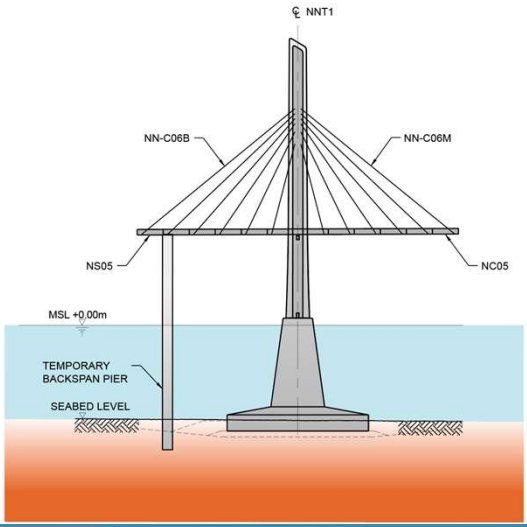
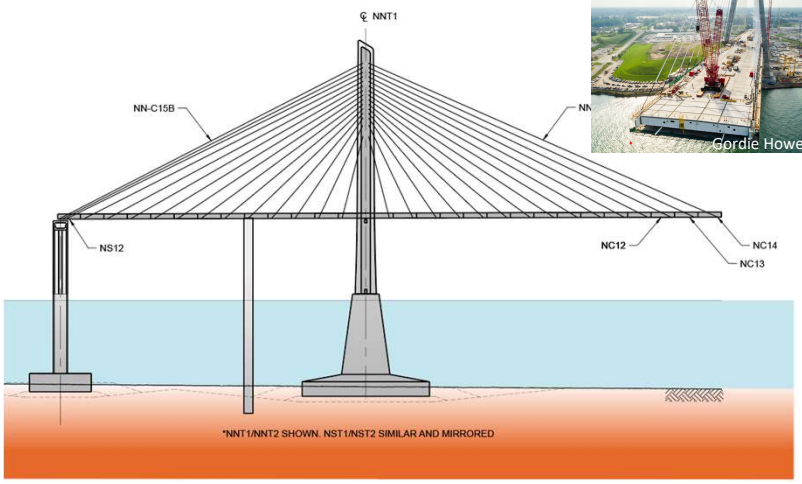


Stage 3

1. Erect NS02/NC02, NS03/NC03, NS04/NC04, and NS05 similar to sequence in stage 2 steps 1 thru 6.
2. Install temporary backspan pier
3. Erect NC05 similar to sequence in stage 2 steps 1 thru 6.

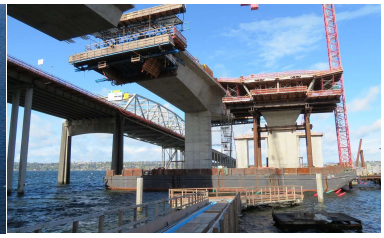
Superstructure erection



Stage 4

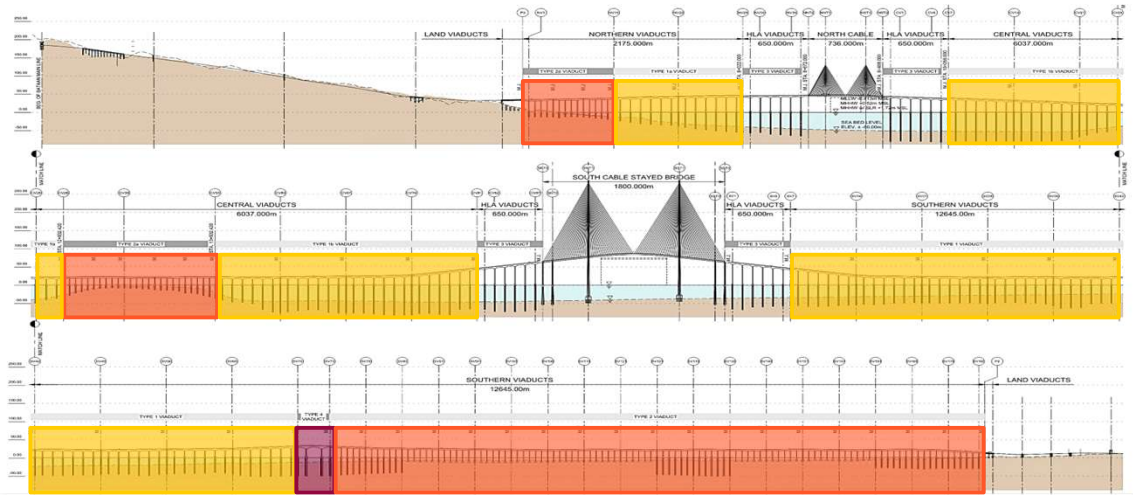
1. Erect NS06/NC06, NS07/NC07, NS08/NC08, NS09/NS10/NC10, NS11/NC11 with spider frame similar to sequence in stage2 steps 1 thru 6
2. Erect field section NS12 steel and cast deck concrete
3. Erect field segment NC12 steel
4. Install cables NN-C13B and NN-C13M and stress to initial loads
5. Place NC12 deck panels
6. Tune/adjust cable NN-C13B and NN-C13M
7. Pour NC12 longitudinal and traverse CIP joints between deck panels and along edge girders
8. Composite adjust cables NN-C13B and NN-C13M
9. Erect NC13 and NC14 similar to NC12 with cables NN-C14B/NN-C14M and NN-C15B/NN-C15M

Marine Viaducts: Construction Driven Design



60m span length	100m span length	133m span length
• **Span-by-span precast segmental construction using overhead gantry will be used** • Adopted at shallow water areas with water depth <10m	• **Girders erected using precast full-span segments and floating cranes** • Adopted at deep water areas • Minimizes schedule and construction cost of foundation and superstructure	• **Cast-in-place segmental balanced cantilever construction using form travellers** • Adopted at the span over the 100m-wide Nearshore Navigational Channel

Span Arrangement



60m span modules ~ 8.9 km | 100m span modules ~ 11.7 km | 91m-133m-91m span module ~ 0.3 km

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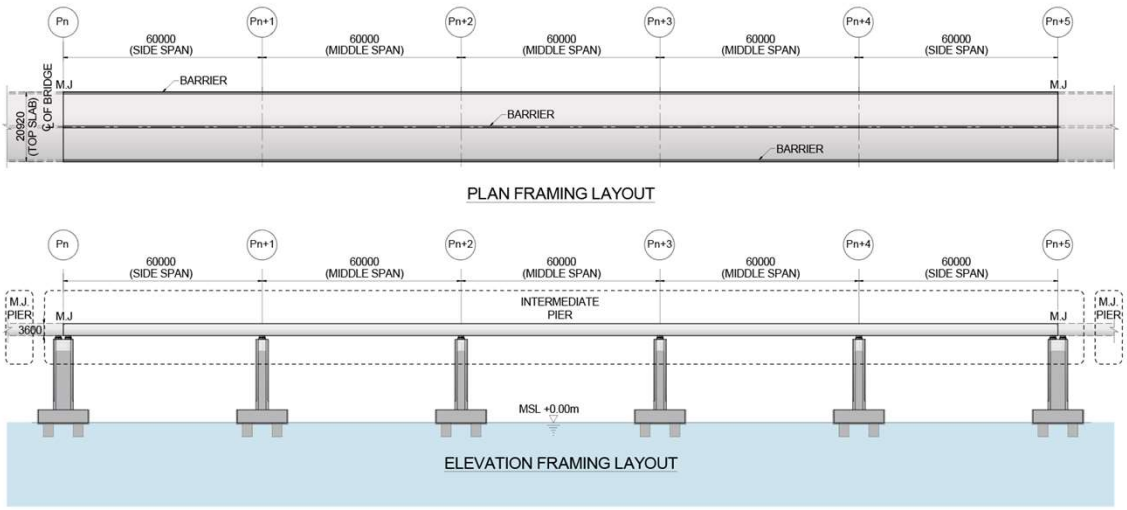
60m Span Module



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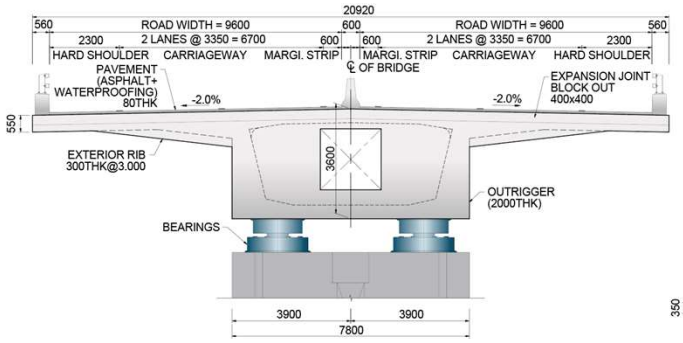
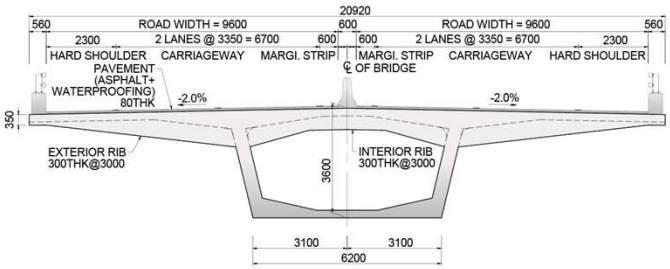
60m Span Module: *Box Girder Deck*

TYLin



SECTION AT MODULAR EXPANSION JOINT

- **Superstructure**
  Precast Concrete Box
- **Rebar Grade**
  Deformed Steel bar: Grade 420 MPa
- **Concrete Strength**
  f'c = 45 MPa (Precast Segments and CIP joints)



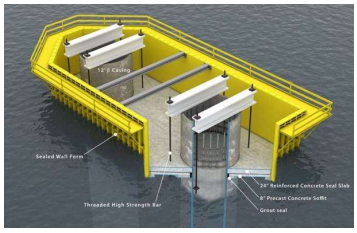
SECTION AT TYPICAL MIDSPAN

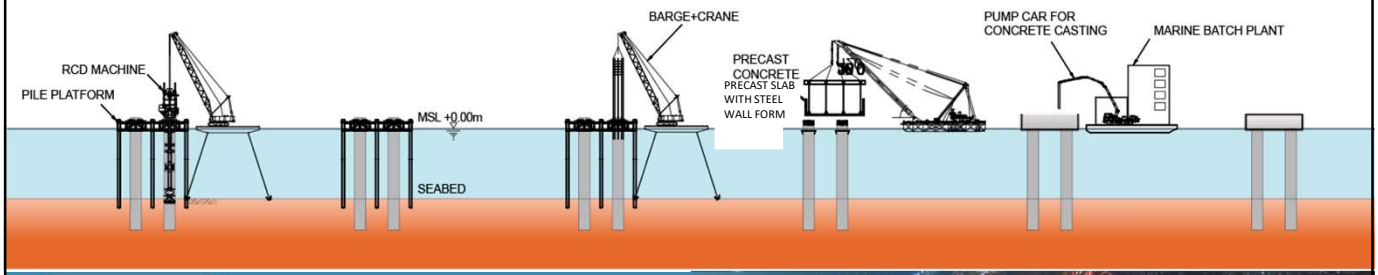
Construction Sequence (Marine Viaduct) 60m span module (Phase 1)

TYLin

CIDH Pile Erection using Reverse Circulation Drilling

Pile Cap Erection using Precast Slab with sealed steel wall forms

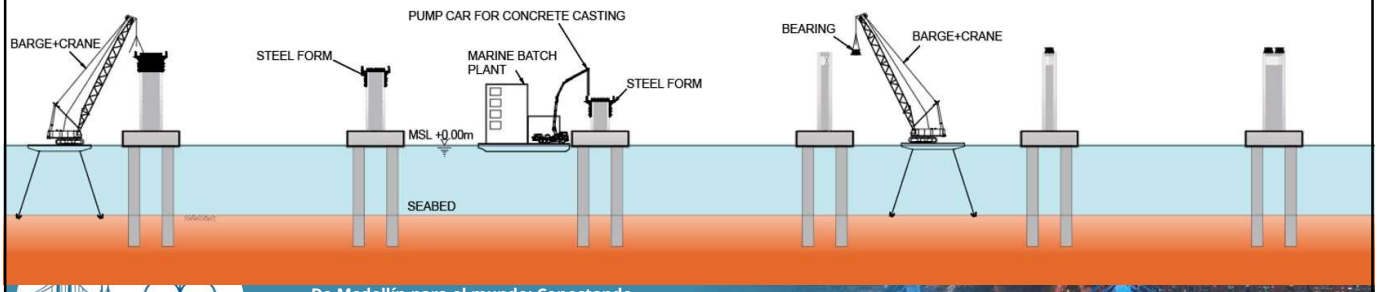




TYLin

Construction Sequence (Marine Viaduct)
60m span module (Pha

Pier Erection



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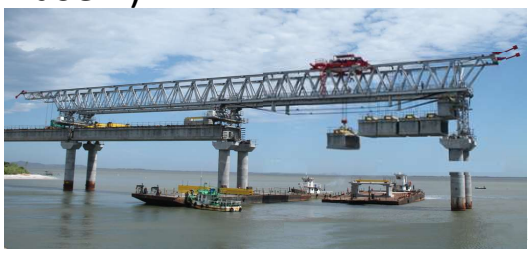
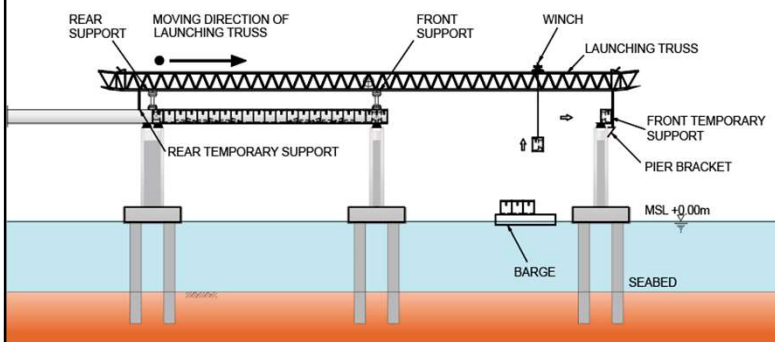
Construction Sequence (Marine Viaduct)
60m span module (Phase 4)

Erection using Launching Truss





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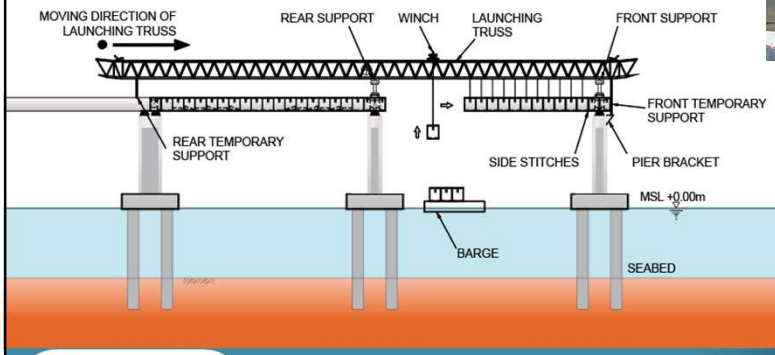
Construction Sequence (Marine Viaduct)
60m span module (Phase 5)

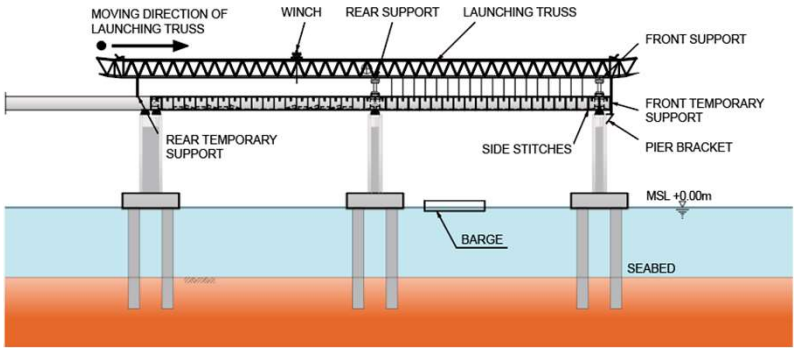
Lifting and positioning of each segment



TYLin

Construction Sequence (Marine Viaduct)
60m span module (Phas

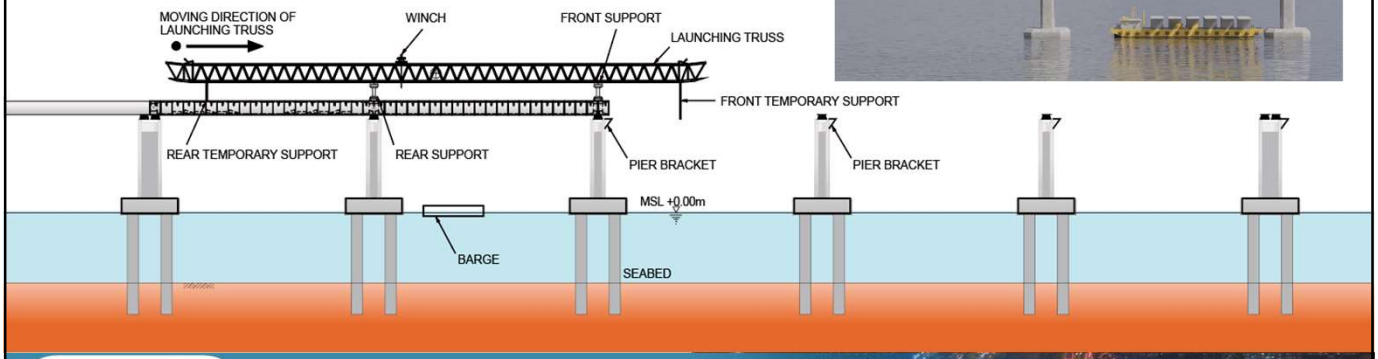
Segment assembly and post-tensioning



TYLin

Construction Sequence (Marine Viaduct)
60m span module (Ph...7)

Launching of erection gantry



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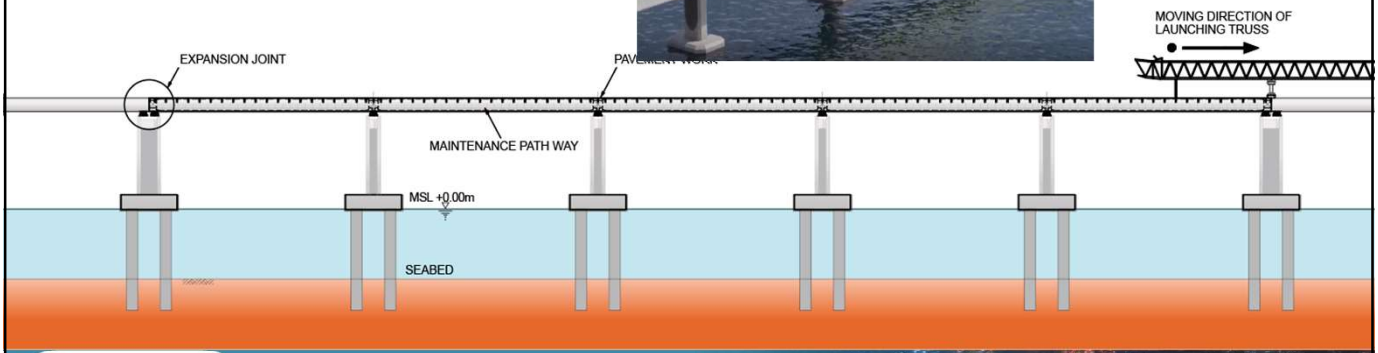
Construction Sequence (Marine Viaduct)
60m span r...

Finishing work



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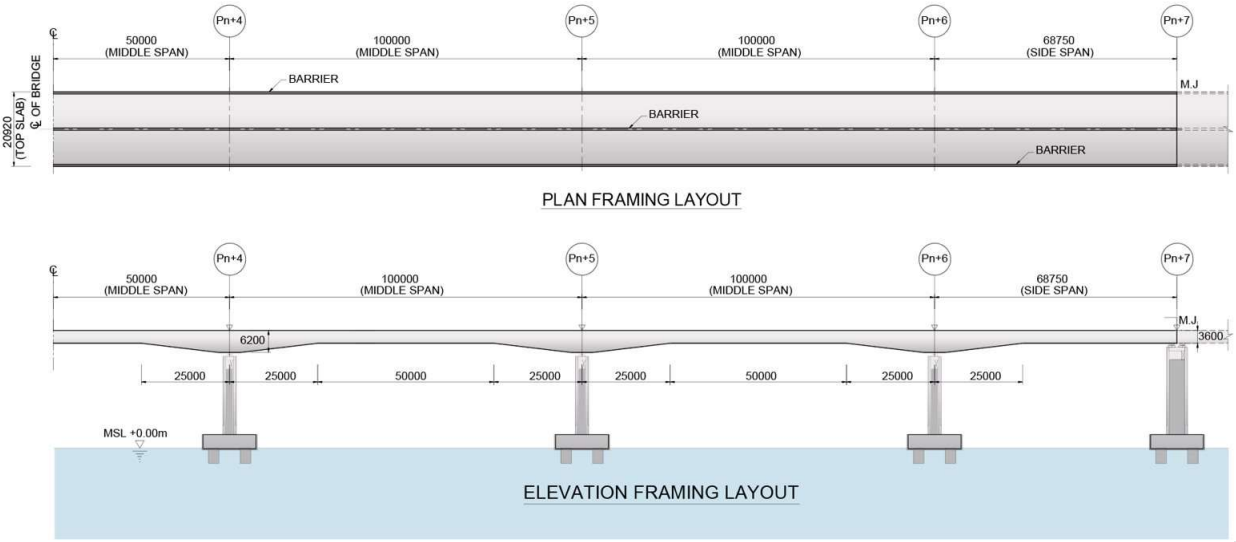
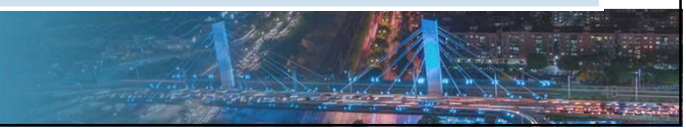
100m Span Module *half frame shown*

TYLin

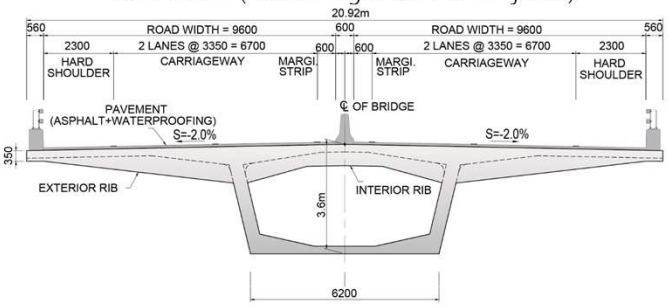




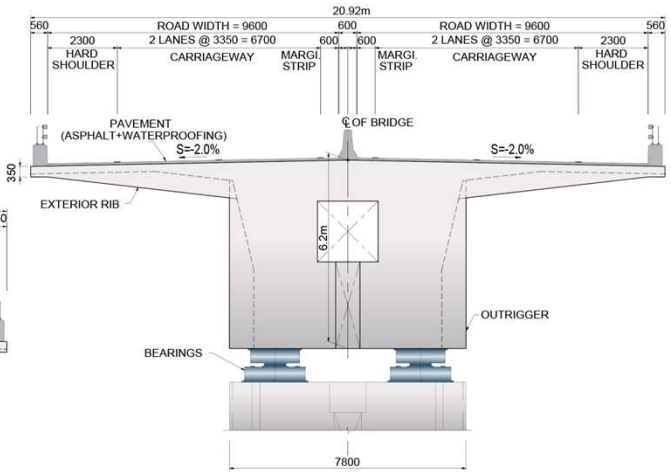
100m Span Module: *Box Girder Deck*

TYLin

- **Superstructure**
  Precast Concrete Box
- **Rebar Grade**
  Deformed Steel bar: Grade 420 MPa
- **Concrete Strength**
  f'c = 45 MPa (Precast Segments and CIP joints)



SECTION AT TYPICAL MIDSPAN



SECTION AT TYPICAL SUPPORT

Construction Sequence (Marine Viaduct)

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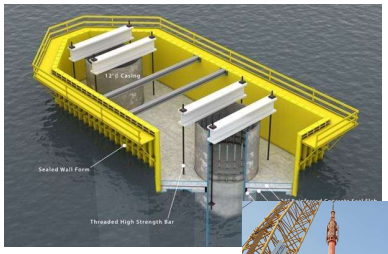
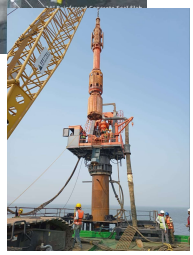
100m span module (Phase 1)

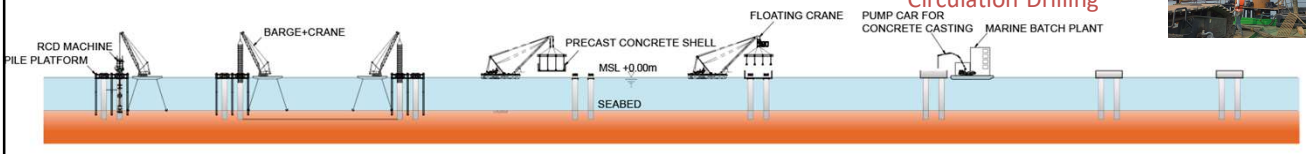
- Install permanent non-structural steel casing
- Excavation and cleaning the hole
- Place the reinforcement cage and pour the concrete for pile
- Install concrete precast shell
- Assemble reinforcement and pour the concrete for pile cap

Pile Cap Erection using Precast Slab with sealed steel wall forms





CIDH Pile Erection using Reverse Circulation Drilling



Construction Sequence (Marine Viaduct)
100m span module (Phase 2)

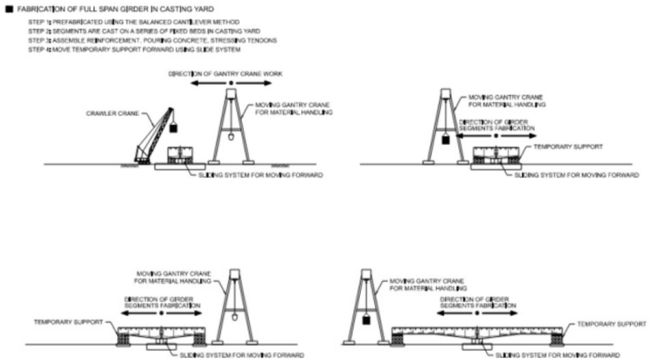
- Install steel form for pier shaft erection
- Assemble reinforcement and pour the concrete for pier
- Install thread bars for temporary fixing between pier table and pier cap
- Assemble reinforcement and pour the concrete for pier cap
- Install bearings on pier cap

Pier Erection

100m span Full Cantilever Fabrication

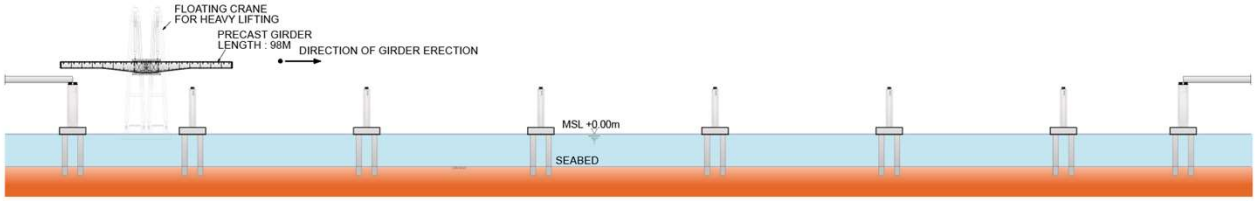
- Precast Cantilever Span Casting (full span girder L = 98m)

- Fabrication Sequence

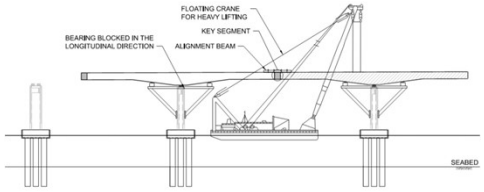


Construction Sequence (Marine Viaduct)
100m span module (Phases 3 to 5)

- Prefabricated full span girder (L = 98m) is moved to site by marine heavy-lifting crane



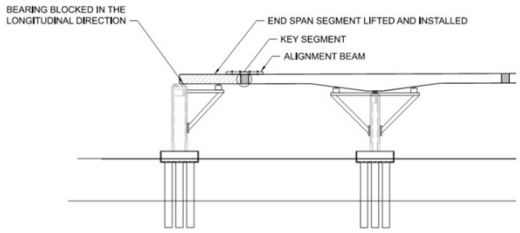
- Erection of Next Full Cantilever and cast Key Segment

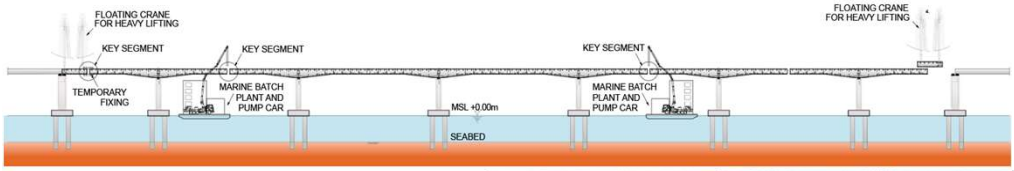


Construction Sequence (Marine Viaduct)
100m span module (Phase 6)

Erection of remaining full cantilever spans and install end span segments

- Erect and position the prefabricated end span.
- Adjust final alignment of girders with alignment beam at end span segment and key segment.
- Cast key segment (side span and center span).
- Prestress the span tendons at mid span and end spans when the concrete stressing compressive strength has reached.
- Dismantle temporary supports and alignment beam





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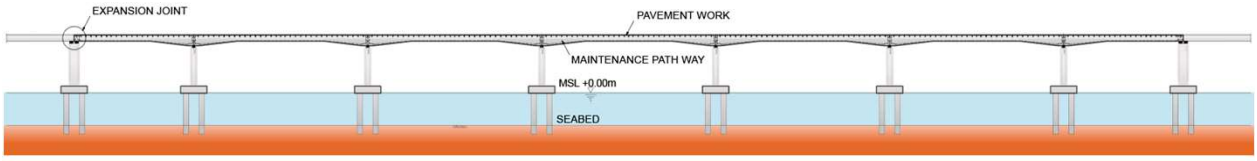
100m span module (Phase 7)

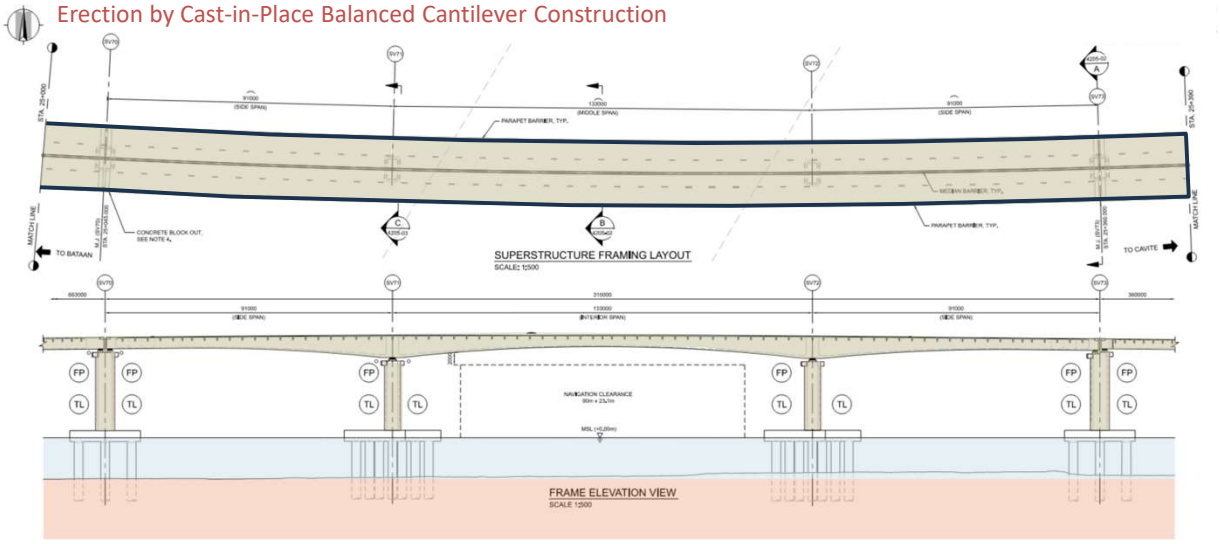
Finishing Works

- Install expansion joint
- Install median and side barrier, pavement work
- Install maintenance pathway frame inside girder



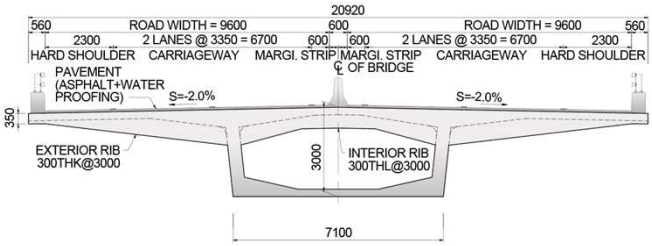
91m-133m-91m Span Module @ *Nearshore Channel*

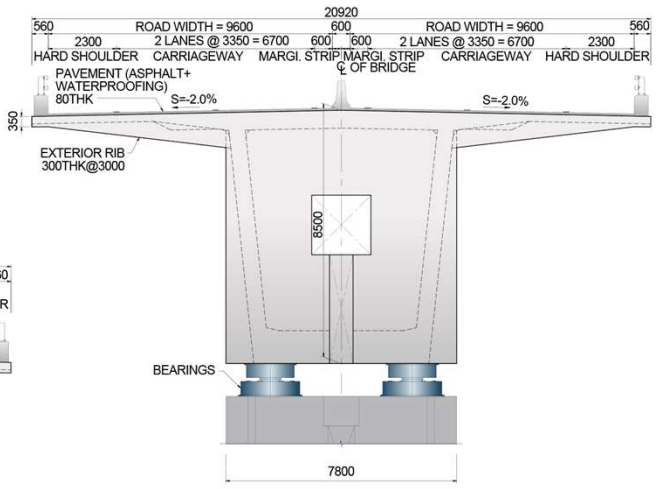
Erection by Cast-in-Place Balanced Cantilever Construction



Superstructure *133m span*

- **Superstructure**
  Cast-in-place Segmental Concrete Box
- **Rebar Grade**
  Deformed Steel bar: Grade 420 MPa
- **Concrete Strength**
  f'c = 45 MPa (Segments and CIP joints)





91m-133m-91m Span Module – Balanced Cantilever

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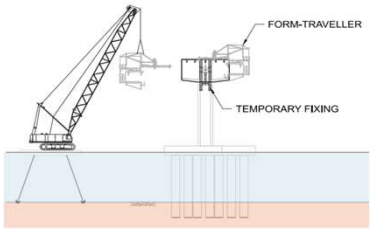
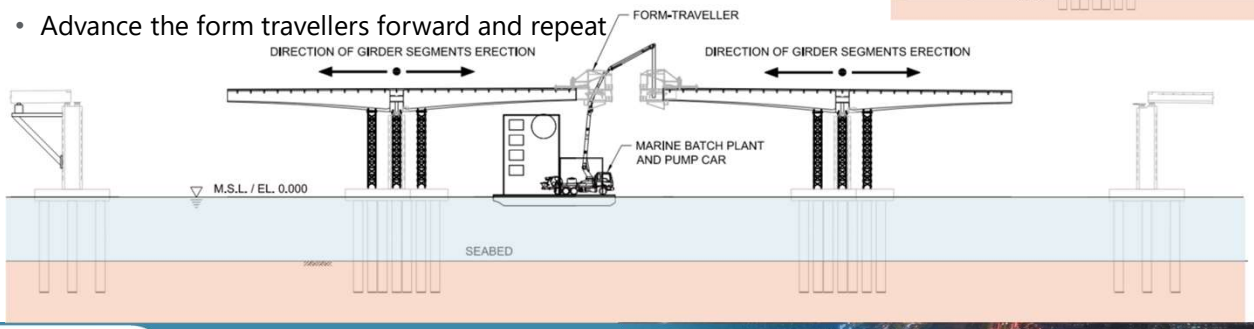
Erection of CIP Box Girder Segments

- Install CIP Form Travellers at both ends of Pier Table
- Stabilize Pier Table with temporary supports
- Install rebar and cast segments
- After concrete reaches strength, prestress the Cantilever tendons
- Advance the form travellers forward and repeat





Samuel De Champlain Bridge Corridor Project

TYLin

- **Resumen del proyecto**
- **Criterios de diseño y desafíos específicos del sitio**
- **Durabilidad**
- **Construcción Acelerada de Puentes (ABC)**
- **Operación y Mantenimiento (O&M)**

Samuel De Champlain Bridge Corridor Project

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Factoids:

- $4.2 Billion CDN PPP (DBFOM) Project ($1 CDN = $0.77 USD)
- $2.2 Billion CDN Design-Build Component
- Contract awarded June 2015
- Opened to vehicular traffic July 1, 2019
- Opened to light rail traffic July 2023

Our Role:

- Managing Partner of Bridge Design Joint-Venture
- Engineer-of-Record of the Cable-Stayed Bridge

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Project Location – Montreal, Canada

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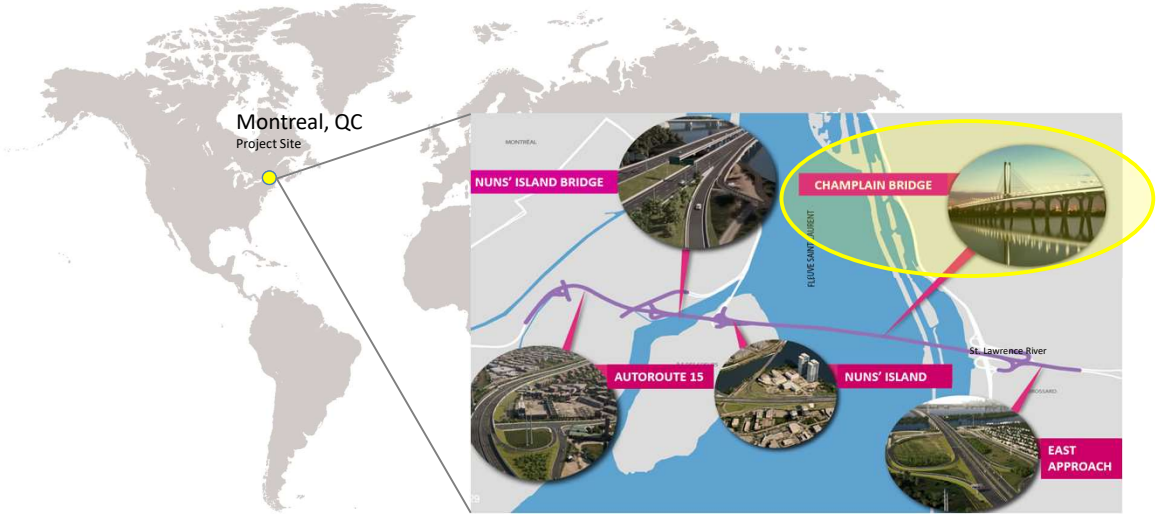

Project Description – 3.4 km

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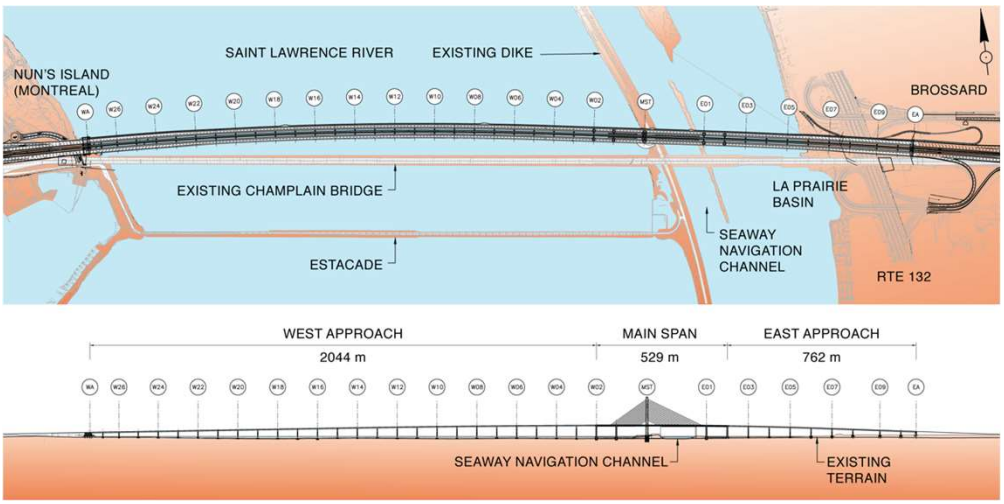
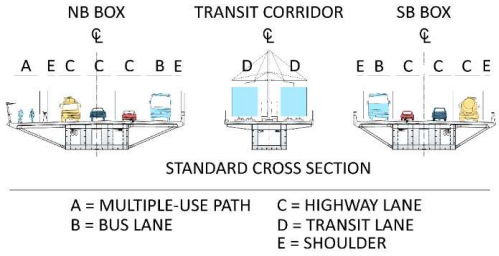


Project Description

- 60 m in width
- 3 Corridor Design
  - 4 traffic lanes on Northbound and Southbound Highways
  - Transit corridor for Light Rail
  - Multi-use path for cyclists and pedestrians
- Lifeline bridge
- 125-year design life



Project Context and the Need for ABC

1986

- First prestressed concrete girder repaired

1991 to 1992

- Replacement of the reinforced concrete deck by orthotropic steel deck

2011

- Federal Government announced replacement of a new bridge upon review of the feasibility studies

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Project Context and the Need for ABC

2013

- Reports indicated the old bridge was reaching the end of its useful life. Gov. of Canada announced that it would accelerate its replacement

Oct. 2013

- JCCBI closes a traffic lane after the appearance of a flexural crack at mid-span of an edge-girder

Dec. 2013 / May 2014

- Installation of emergency super-beam followed by emergency modular truss

Feb. 2014

- RFQ is issued followed by RFP in July 2014

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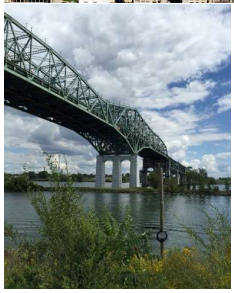
Need for Replacement

- One of North America's Busiest Crossings (60M vehicles per year)
- Original Bridge (Built 1962)
  - Exposure to de-icing salt
- High Maintenance Expense
  - Major rehabilitation works
  - From 2011-2016, more than $300 M CDN over 6 years period
- Two lane closures incidences late 2013
  - Appearance of a flexural crack at mid-span of an edge-girder
  - Urgent need for replacement



Reference: *Pre-feasibility Study of the Replacement of the Existing Champlain Bridge – Summary Report, March 31, 2011*

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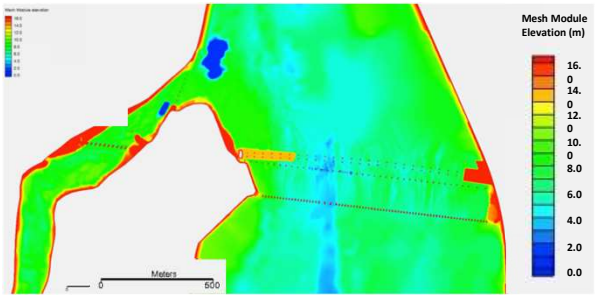
Technical Challenges

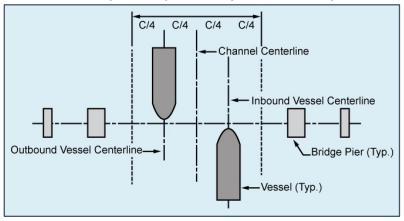
- Extreme Temperature
  - Varying from -34°C (-29.2°F) to above 30°C (86°F)
- Ice accretion, Ice loading, Ice abrasion
- Wind, Seismic, Vessel Collision, Scour
- Channel Closure 4 months in a year
- "No Construction Zone" in Seaway
- Challenging field construction

Design Criteria

- Scour
  - 100 year flood
  - Design for Scour Range
- Vessel Collision
  - Class 1 critical bridge
  - Vessel types that navigate through and adjacent to the Saint Lawrence Seaway
  - Maximum annual frequency of collapse of 1/10,000



Bathymetry in Project Vicinity



Passing Vessel Transit Paths in Channel through Bridge

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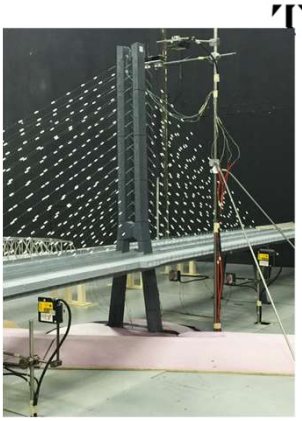
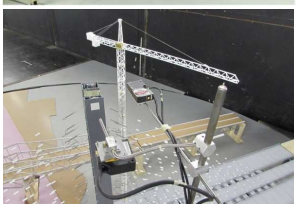
Wind Design - Wind Tunnel Studies

- Wind Climate Study
  - Design wind speeds (at deck height):
    - 20-year RP for construction = 27.5 m/s
    - 125 year RP for strength design = 33 m/s
    - 10,000 years for aerodynamic stability = 48 m/s
- 1 to 50 scale section models of deck & tower legs (WWL)
  - Static tests, aerodynamic derivative tests, Load Analyses – stable to 70 m/s
- Equivalent Static Load Analysis (BLWTL)
- 1 to 150 Scale Full Aeroelastic Model Tests (BLWTL)
  - Completed Bridge
  - Critical Cantilever Construction Stages

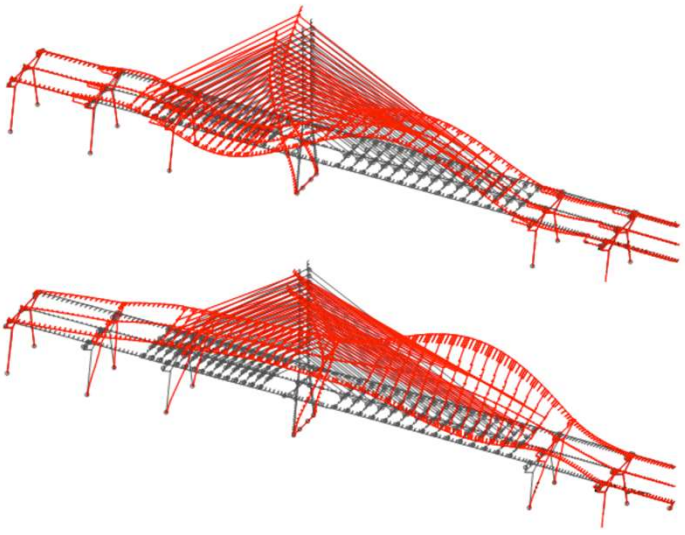




BLWTL = Boundary Layer Wind Tunnel Laboratory
ARA = Applied Research Services Inc.
WWL = West Wind Laboratory inc

Seismic Design

- Factor demands of 2475-year event by 1.3
- Capacity is the un-factored ultimate resistance
- Seismic detailing not required
- Material strain checks not required



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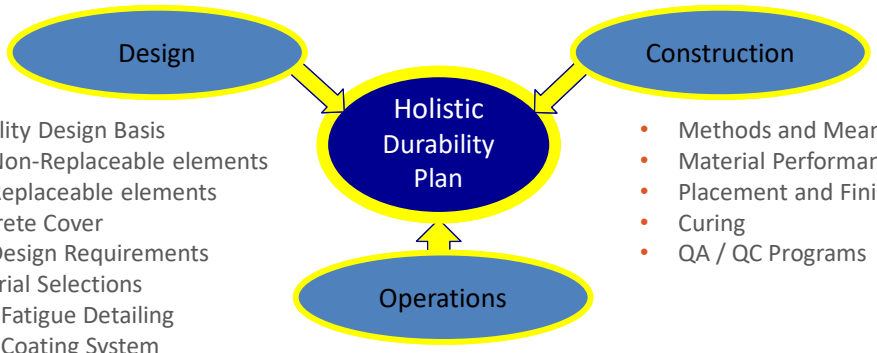
Achieving 125-year Design Life

- Holistic Approach to Durability Plan



- Durability Design Basis
  - Non-Replaceable elements
  - Replaceable elements
- Concrete Cover
- Mix Design Requirements
- Material Selections
- Steel Fatigue Detailing
- Steel Coating System
- Access to Inspection
- Good Drainage Details

- Methods and Means
- Material Performance Testing
- Placement and Finishing
- Curing
- QA / QC Programs

- Structural heath monitoring
- Inspections
- Maintenance
- Future Replacement / Repairs

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Design - Service Life Modeling

- Determine environmental exposure (i.e. de-icing salts)
- 4 Concrete mixes were specified. High performance mixes (with silica fume and fly ash) were used in areas most susceptible to exposure (i.e. superstructure)
- Supplemental corrosion protection system (i.e. calcium nitrate corrosion inhibitor)
- Rebar materials (i.e. stainless steel, galv steel)
- Concrete cover
- Probabilistic analysis (with use of STADIUM® modeling software) to estimate time-to-corrosion initiation

Input Variable	Mix 1	Mix 2	Mix 3	Mix 4
STADIUM Transport Properties[1]				
Ion Diffusion Coefficient, IDC (e^{-11} m^2/s)	1.0	2.0	3.0	4.0
Moisture Transport Coefficient, MTC (e^{-22} m^2/s)	15	15	15	15
Porosity (%)	12.5	12.5	12.5	12.5
STADIUM Aging Parameters				
Hydration Parameter, a	1.00	1.00	1.00	1.00
Hydration Parameter, α	1.0000	1.0000	1.0000	1.0000
Maximum CSA A23.2-23C Acceptance Criteria during Production[2]				
Rapid Chloride Permeability, C	800	800	1000	1500

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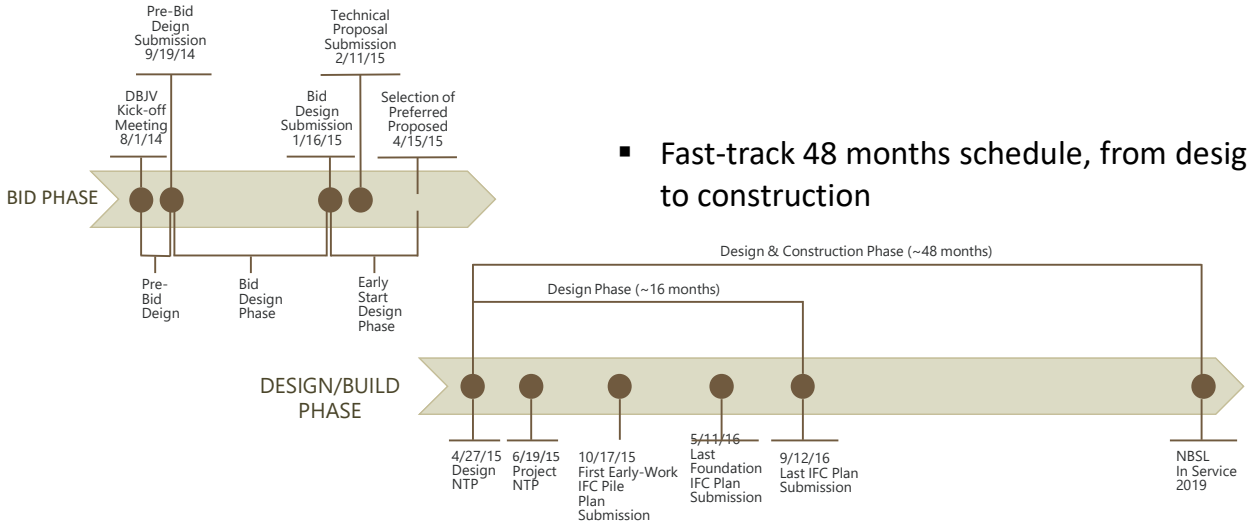
Fast-track Schedule



- Fast-track 48 months schedule, from design to construction

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Accelerated Bridge Construction (ABC) in Mega Scale

Design for Accelerated Bridge Construction

- Maximize use of modular construction
- Precast concrete elements; minimize cast-in-place
- Pre-fabricated steel elements with field bolting
- Avoid delays due to severe cold weather
- Prefabrication provides for better quality control
- Efficient construction schedule

Credit: @ThomasHeinser

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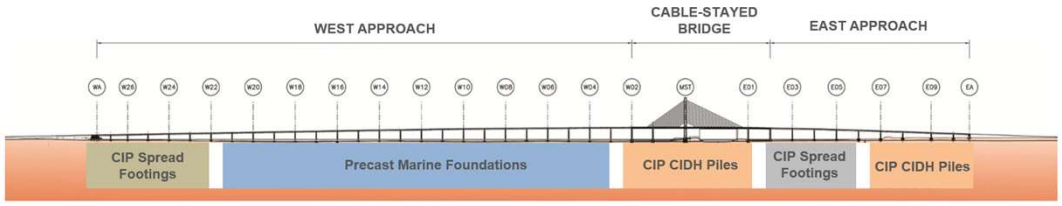
Maximize Use of Modular Construction - Foundations

Approaches:

- 33 total approach piers:
  - 25 West Approach:
    - 6 cast-in-place (CIP) spread footings
    - 19 precast marine foundations
  - 8 East Approach:
    - 4 CIP spread footings
    - 4 CIP pile caps with 8 – 1.2m (4') dia. cast-in-drilled hole (CIDH) piles

Cable-Stayed Bridge:

- 4 Total CSB piers and MST Tower:
  - W01/W02/E01: CIP pile caps with 6 – 1.2m (4') dia. cast-in-drilled hole (CIDH) piles ea.
  - E02: CIP spread footings
  - MST: CIP footing
    - 2 pile caps (pods). Pods are linked with tie beams
    - 2 x 21 - 1.2m (4') dia. piles each pod



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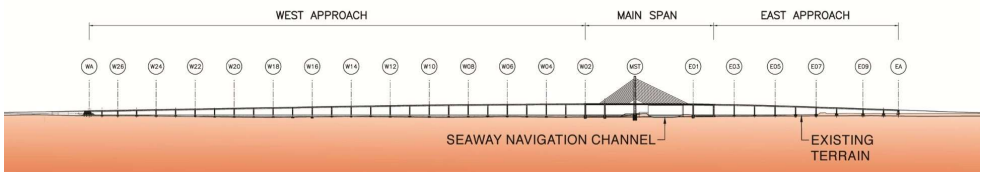
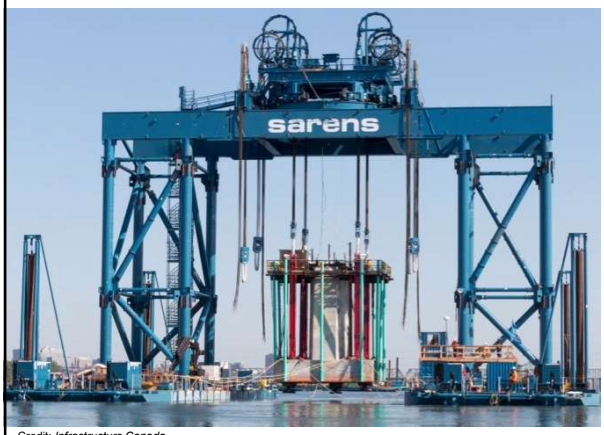
Design - Optimizing Span Lengths in Approaches

- Concrete Option
  - Constant depth concrete girder
  - 60m spans, ~50 piers, but more foundations
- Steel Option
  - Constant depth steel girder (i.e. OGB)
  - 100m spans, ~30 piers, but costly
- Composite Option (Chosen)
  - 80m-84m spans, 37 piers

- Composite deck option for the superstructure has the best balance: saved time, cost, and reduced in-water works



Heavy Lift Foundation Setting (Weight 600 ~ 1000 MT)



Credit: *Infrastructure Canada*

- Precast spread footing w/ pier starter
- Custom-built floating installer

- Sacrificial jacks for leveling/tremie concrete
- 2-3 days per foundation

Pier Bents

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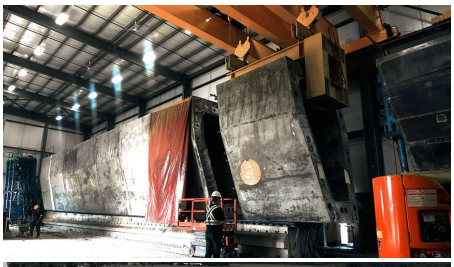
Precast Pier Bent



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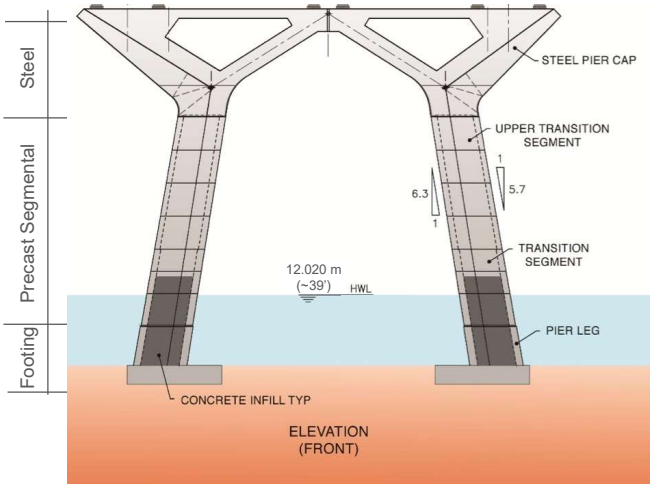
Pier Bents

- Prescribed architectural appearance per Definition Drawings
- Pier shapes are common to approaches and cable-stayed bridge
- Precast pier bent segments
- Post-tensioning tendons are used in pier legs
- Post-tensioning extends from W-frame down into footing loop tendons
- W-Frame anchored to piers via post-tensioning



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De Medellín para el mundo: Conectando saberes, construyendo futuro

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Concrete Characteristics

(1 MPa = 145 psi, 60 MPa = 8702 psi)

Component	f'c	Characteristics	w/cm
Deck slab panels (cable stayed bridge)	70MPa	Precast	0.30
Deck slab panels (approach spans)	60 MPa	Precast	0.32
MST (Pylon) - shaft	60 MPa	Precast Lower/CIP Upper	0.30
MST (Pylon) – pile cap	35 MPa	Cast-in-Place (CIP)	0.38
Drilled shaft (deep foundation)	50 MPa	Tremie	0.38
Piers (columns – approach spans)	60 MPa (80 MPa)	Precast	0.32
Piers (footings – approach spans)	35 MPa	Precast	0.38

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Pier Bents and Steel Pier Caps in Construction

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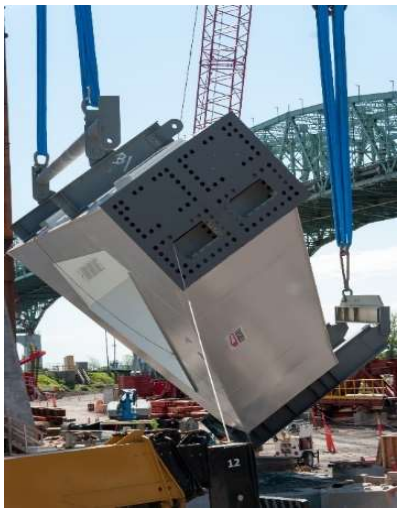
Steel Pier Cap Erection – Lift Weight > 200 MT



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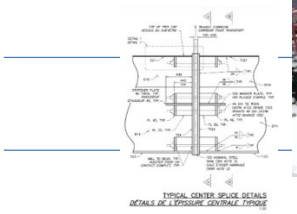
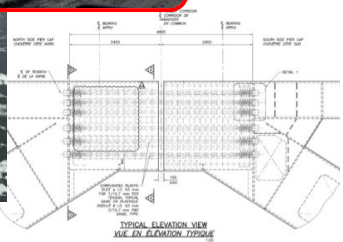
Steel Pier Cap Center Splice

- Pier Cap with Steel Center Splice
  - Weight ~450 MT
- Pier Cap with Concrete Center Splice
  - Weight ~550 MT





Credit: *Infrastructure Canada*

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Cable-Stayed Bridge

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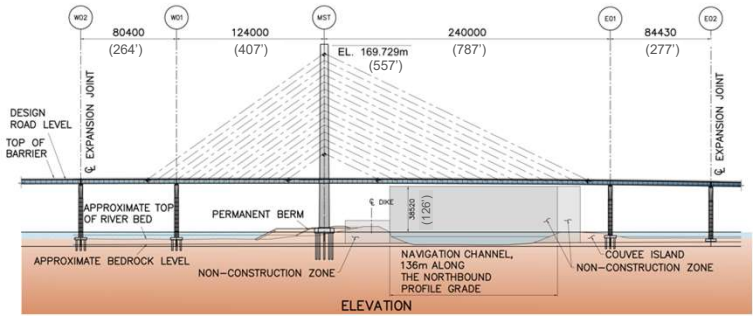
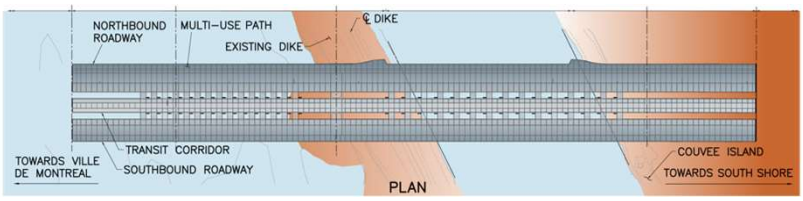
Cable-Stayed Bridge





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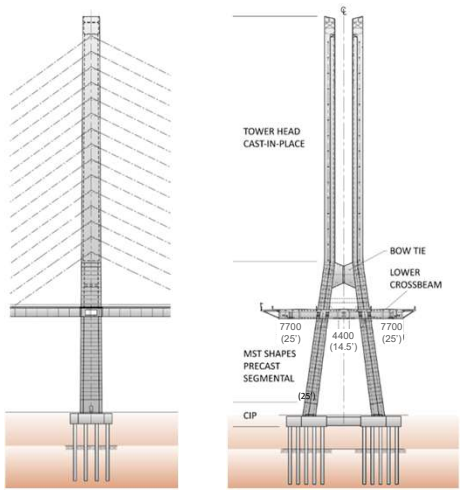
Main Span Tower (MST)

- Post Tensioned CIP footing with CIDH piles
- Lower shafts: Inclined shafts with precast concrete segments
- Upper shafts: cast-in-place concrete segments
- Shafts are braced with a lower crossbeam
  and upper precast crossbeam “bow-tie”



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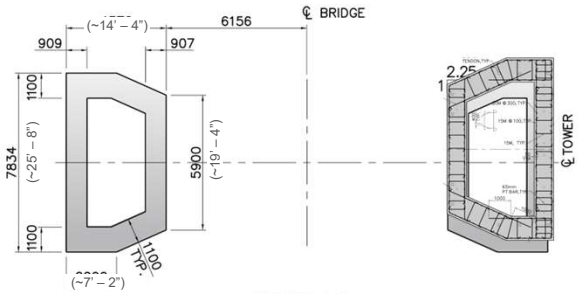
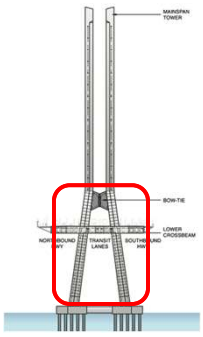
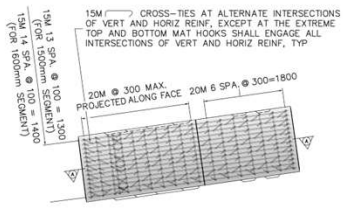
MST Lower Shafts

- Precast segments
- Wt. = 77 MT max
- Hollow concrete box sections stacked atop another
- Post-tensioned
- Joints remain in compression under service loads

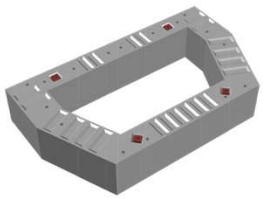






TYPICAL PRECAST SEGMENT WALL REINFORCING

SECTION



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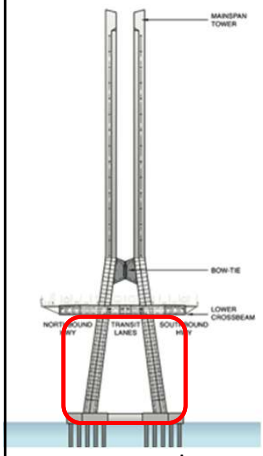
MST Lower Shafts Precast Segmental Construction



- 44 precast lower tower leg segments
- Weight ~ 77 MT
- Up to 3-4 segments erected per day
- Completed in ~40 days

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MST Lower Shafts - Epoxy Joint Mockup & Testing

- Air tightness test conducted 2 days after epoxy
- No leak at the joint validated with soap water
- Pressure kept at 100 psi for 5 minutes with out any loss, as per PTI recommendation
- Drilled core @ 45 deg. showed epoxy on all surfaces
- Cores samples were tested for strength

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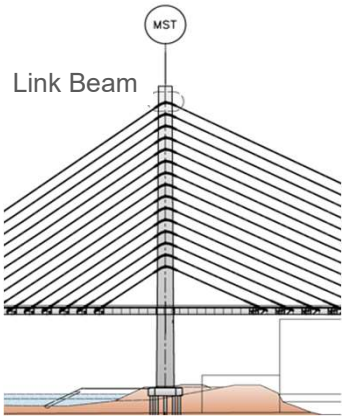
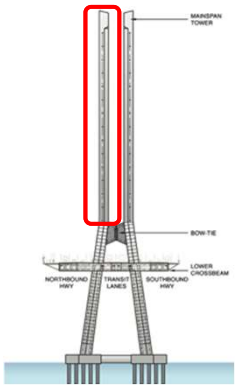
MST Upper Shafts





- 15 cast-in-place upper shaft segments
- 1 lift cast every 2 weeks with jump forms

Credit: *Infrastructure Canada*

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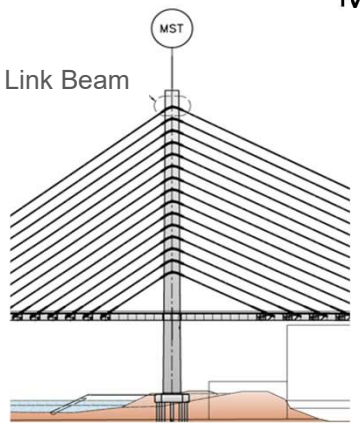
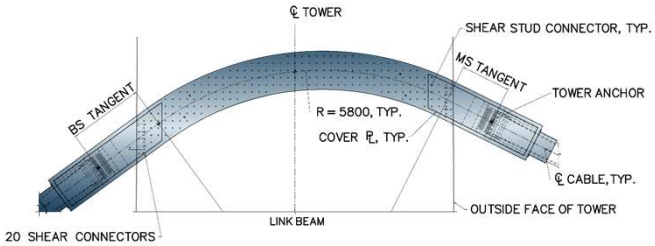
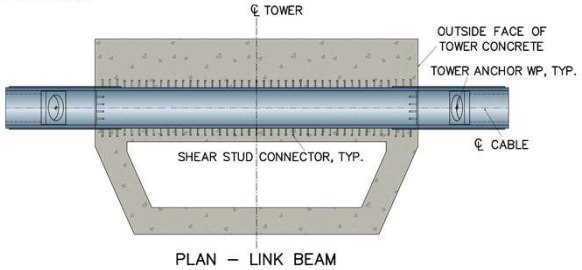
MST Upper Shafts – Link Beam



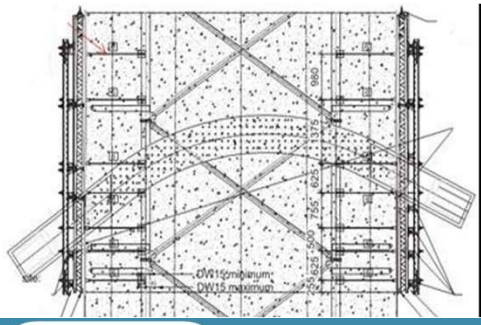


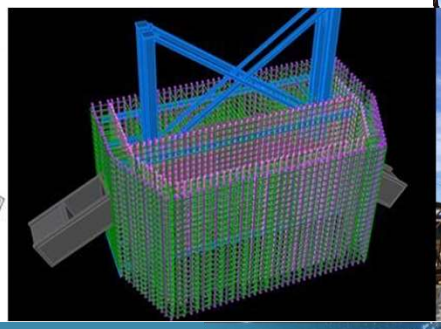


- Composite with tower segment
- Independent anchorages outside of tower
- Allows for modular construction

Link Beam – Integrated Shop Drawing

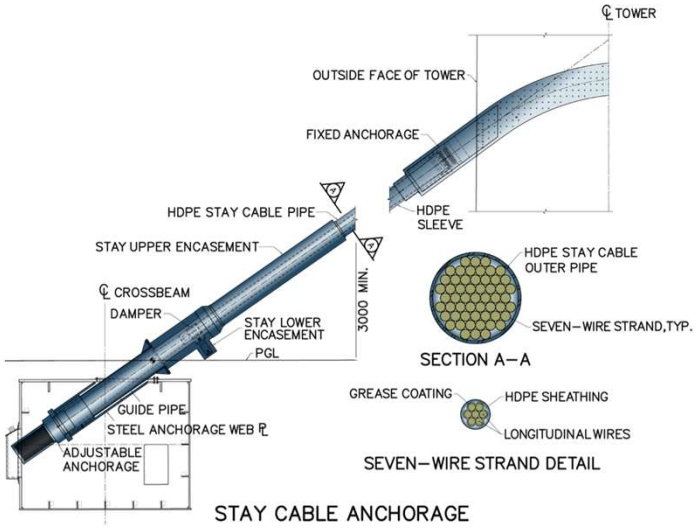
- 3-D integrated shop drawings
- Clash avoidance
- Initial investment in the design phase saves on construction time





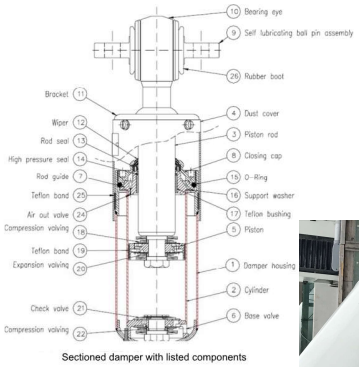
Stay Cable

- 60 total stay cables
- Mainspan: 121-strand cables ea.
- Backspan: 127-strand cables ea.
- Stay is not grouted
- Corrosion protection provided by DSI:
  - Galvanized wire strand
  - Wax and Polyethylene (PE)-Coating
  - HDPE Sheathing
  - Water and airtight anchorage zones



Damping

- Every stay cable includes a twin tube hydraulic telescopic damper for vibration control
- Stay Cable Dampers are needed to mitigate the effects cause by the following sources of vibration:
  - Vortex shedding
  - Rain/wind induced vibrations (RWIV)
  - Galloping due to inclination
  - Wake galloping
  - Galloping due to ice accretion
  - Excitation from vibrations in other parts of the bridge
  - Buffeting from wind turbulences



Sectioned damper with listed components

Wind Tunnel Testing - Full Aeroelastic Model Test

- With existing Champlain bridge and construction tower crane

Stay Cable Testing

- Force Technology and National Research Council (NRC) – Canada
- Testing Program (samples – double helix / 200mm (8”) rings / 300 mm (12”) rings:
  - Static dry tests
  - Passive-dynamic tests with simulated rain
  - Static tests with ice accretion
  - Ice accretion and de-icing tests

Superstructure

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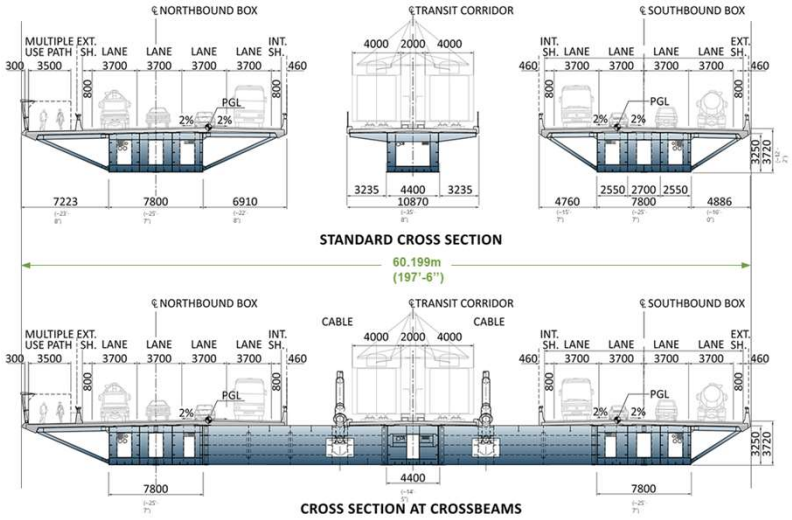
Superstructure – Composite Steel Girder, Precast Deck Panels



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Superstructure – Fabrication in Spain

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Superstructure – Precast Deck Panels

- All deck reinforcement Duplex Stainless Steel: EN 1.4362 (UNS S32304) – 520 MPa (75.4 ksi)
- No. of Panels: 1400 (CSB)
- No. of Panels: 9638 Total

- Shop 1 – Northbound, Southbound panels 5 casting lines
- Shop 2 – Transit corridor 3 casting lines
- Produced up to 50 panels per week

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Superstructure – Precast Deck Panels

- 440 precast deck slab panels installed per week on-site.

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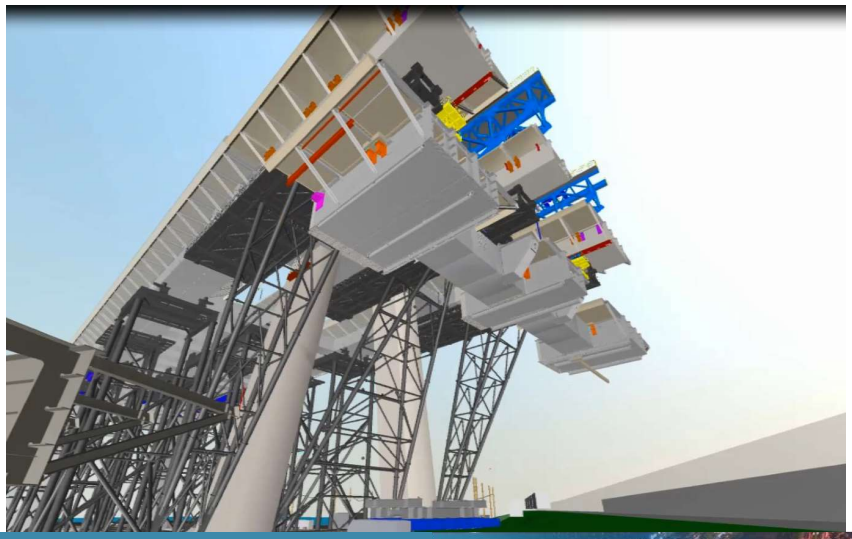
Accelerated Construction Methods – Large Segments



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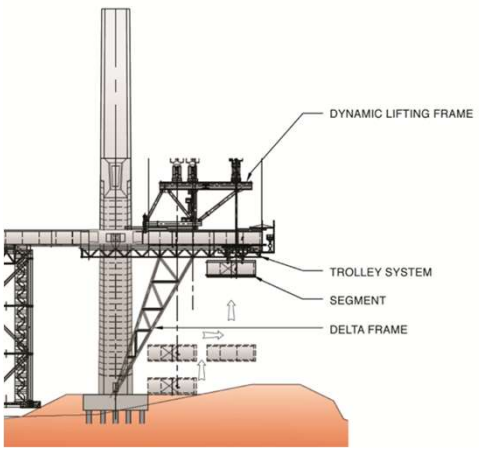
Superstructure Erection - MS1-Segment – 850 MT

- 60m (196’-10’’) x 12.5m (41’) segments



Credit: Infrastructure Canada

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Superstructure Erection - MS1-Segment (Video)

newchamplain.ca/

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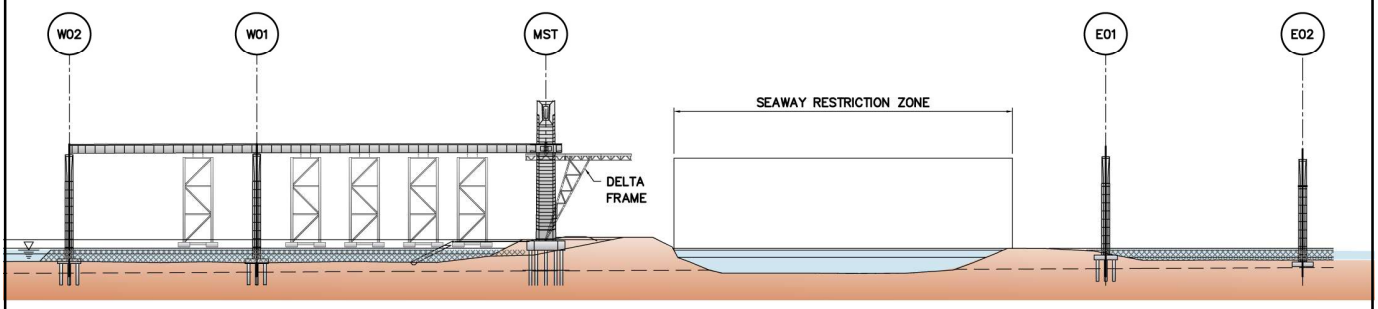
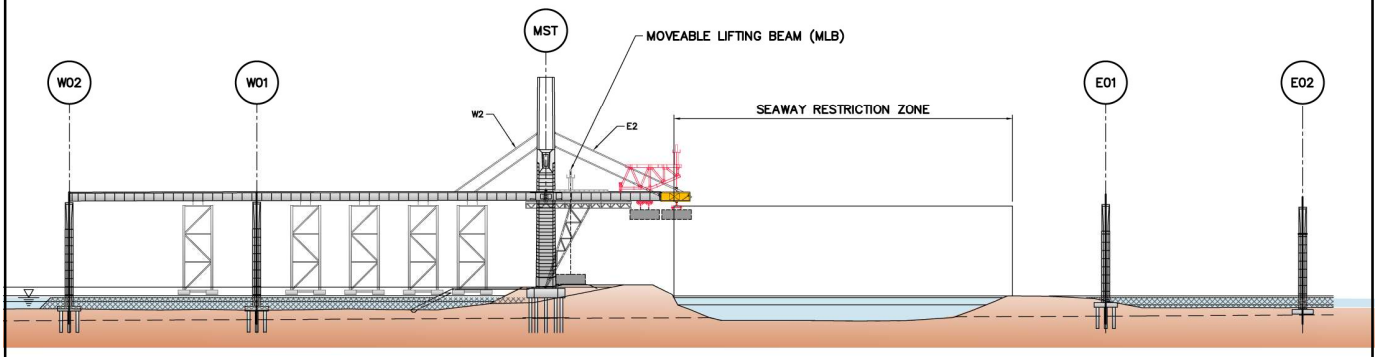
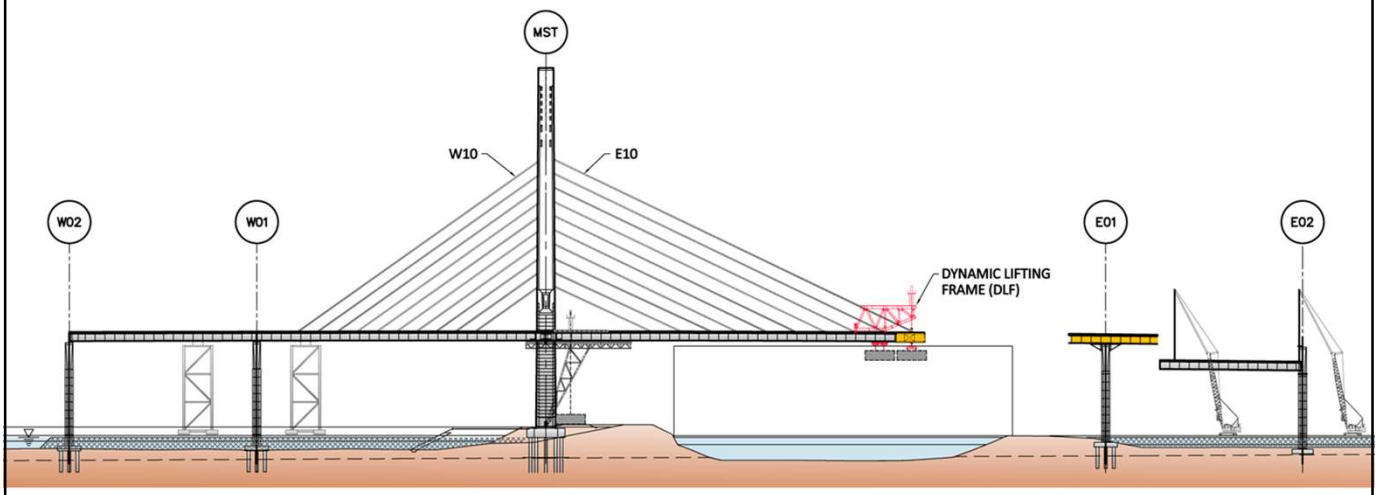
CSB Construction Sequence



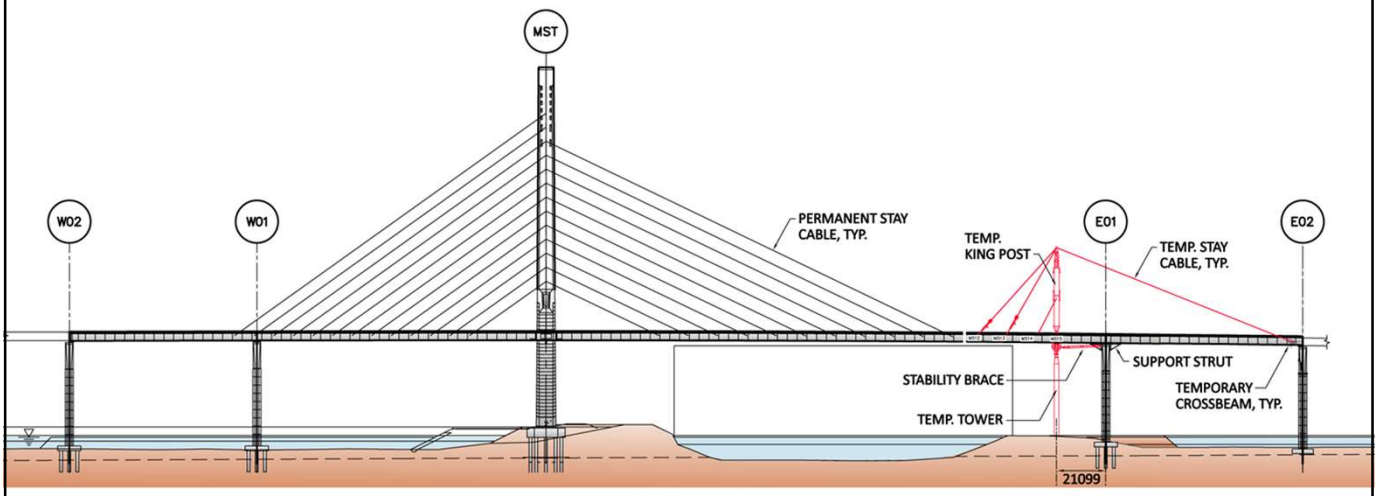
CSB Construction Sequence



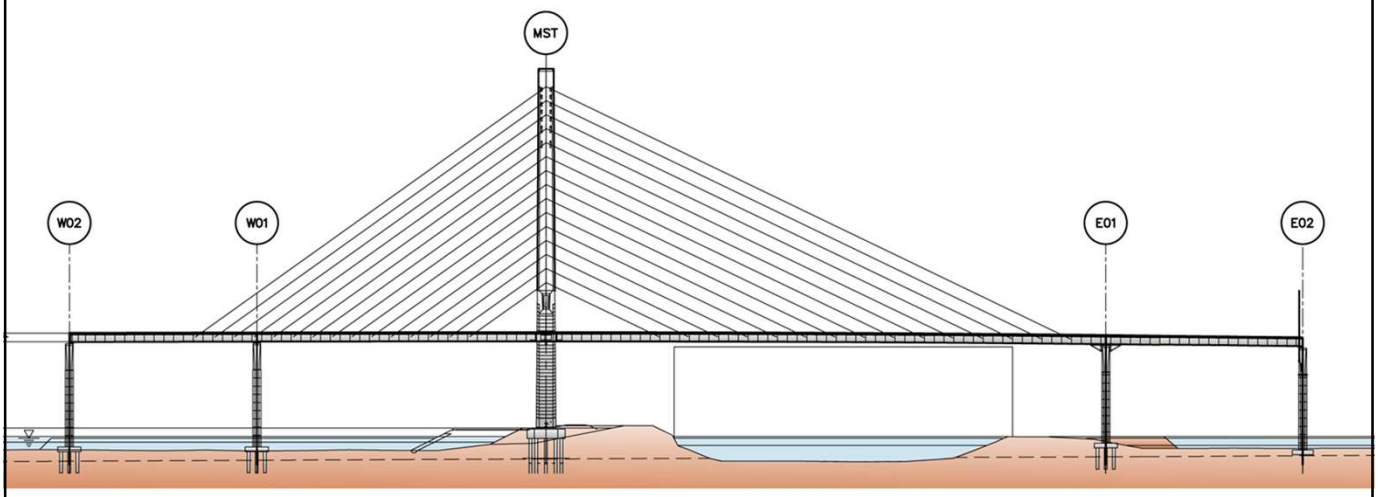
CSB Construction Sequence – Original (MS15-E01)



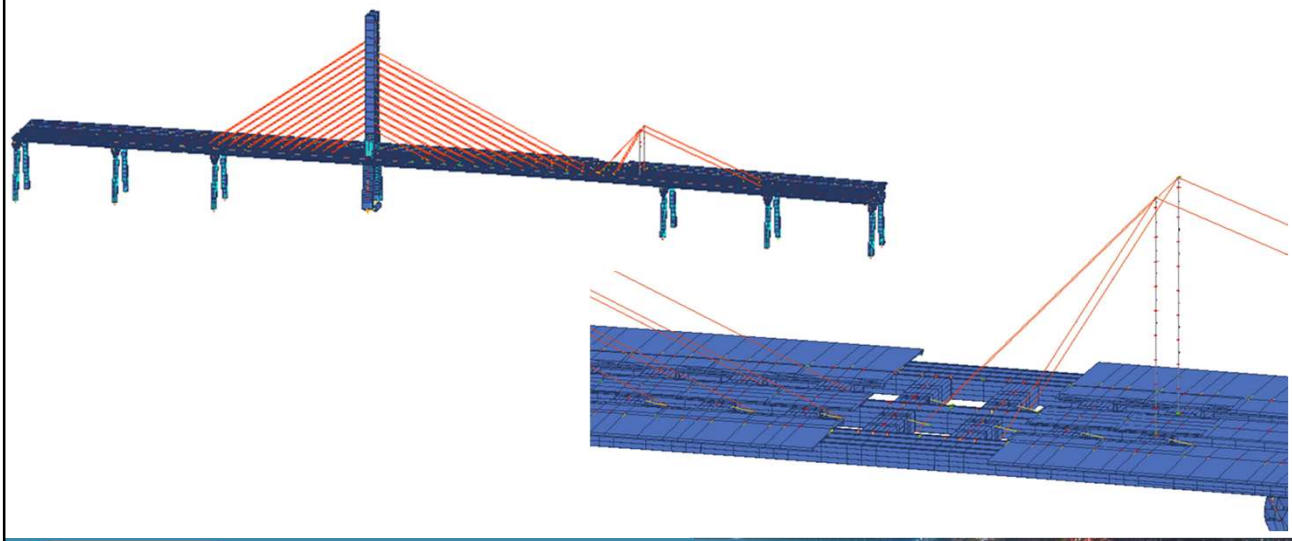
CSB Construction Sequence – Option E” (MS11-MS12)



CSB Construction Sequence



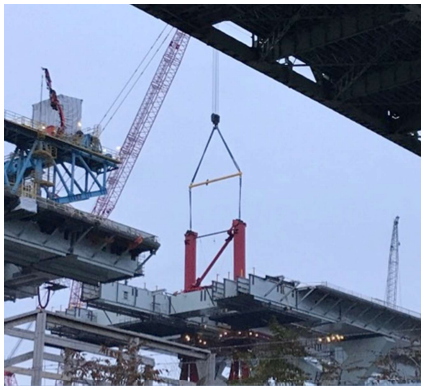
Erection Analysis in RM: Option E”



Alternative Erection Scheme Implemented (2 Months Saved)

King Post Tower (11-01-2018)

Credit: *Infrastructure Canada*



King Post Tower (12-10-2018)

Alignment of MS11, MS12 (02-11-2019)

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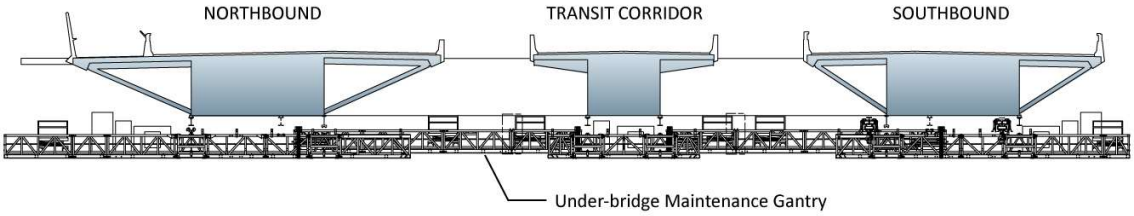
Operation – Maintenance Access Plan

- Under-bridge Inspection Vehicle
- Under-bridge Maintenance Gantry
- Walkways
- Electric Shuttle Vehicle
- Inspection Cradle
- Rope Access System
- Elevator
- Ladders
- Platforms
- Unmanned Inspection Vehicle
- Stay Cable Gantry
- Cross Passage Platform

Shuttleway



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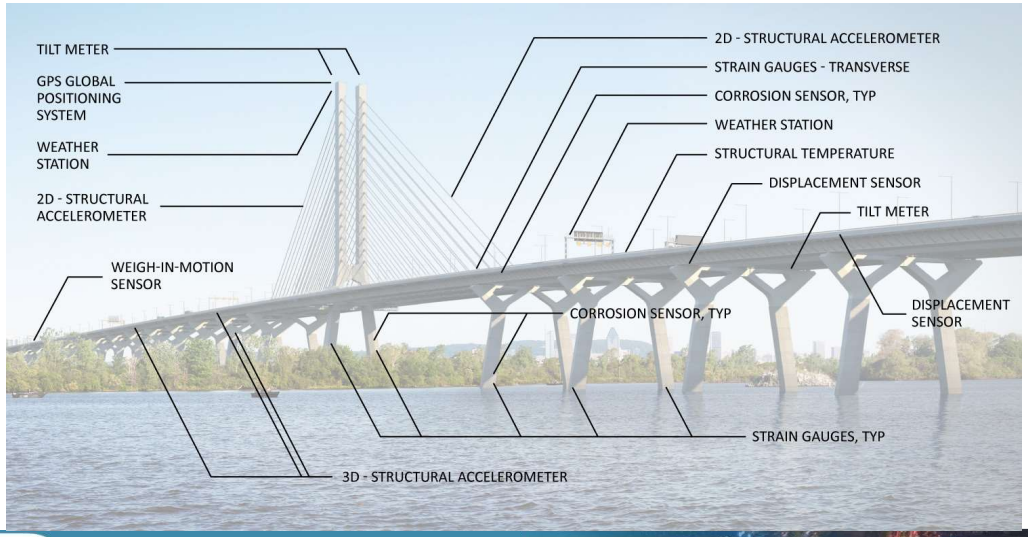
Structural Health Monitoring



Accelerated Bridge Construction (ABC) in Mega Scale (Recap)

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Design for Accelerated Bridge Construction

- Maximize use of modular construction
- Precast concrete elements; minimize cast-in-place
- Pre-fabricated steel elements with field bolting
- Avoid delays due to severe cold weather
- Prefabrication provides for better quality control
- Efficient construction schedule

Credit: @ThomasHeinser

Takeaways

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- Meeting Architectural Vision and satisfying community expectations via Definition Design within a Design-Build, PPP framework. This method worked well
- Heavy Precast Pier Footings successfully placed using Floating Pier Installer despite strong river currents
- Sacrificial Hydraulic Jacks for levelling and use of green joint (above water) to ensure proper final alignment proved successful
- Specialized training required in Quebec for use of stainless steel rebar (rust staining, bar bending, contact between dissimilar materials, etc.)
- Development of special mixes were key in achieving a successful outcome (self-compacting concrete, ternary cement mixes, use of fly ash)
- Environmental protection presented key challenges – particularly during aquatic excavation to rock for marine footings (turbidity curtains, winter conditions)
- Institute for Sustainable Infrastructure (ISI) – targeting Envision Bronze Award, but higher Platinum Level Award achieved – under DB/PPP project delivery method – confirming that such requirements can be embedded within a PPP or DB contract

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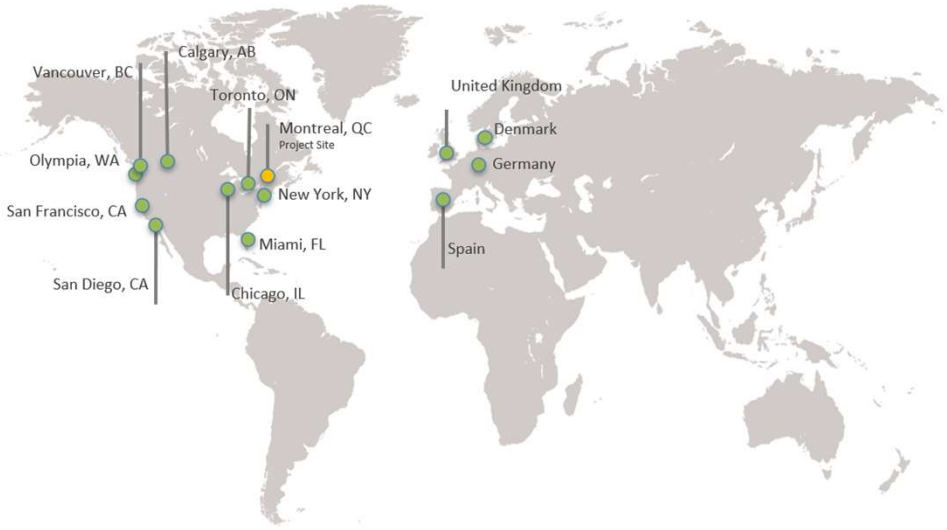
A Global Team



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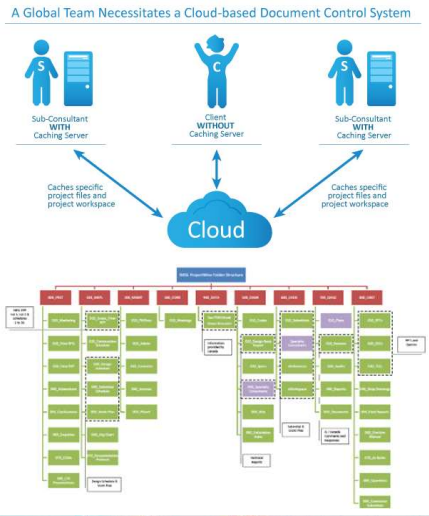
Effective Communication and Collaboration (Cloud Based)

- Change management – Design Quality Plan
- Cloud-based electronic document control system accessible by all design team members from different entities
- Regular scheduled team meetings
- Communication protocols
  - multilingual team
- Quality training
- Expedited reviews and comment resolutions
- CADD integration
- Streamlined communication across different time zones



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Credits

- Owner: Government of Canada
- Developer: Signature on the Saint Lawrence Group
- Contractor: Signature on the Saint Lawrence Construction (Partnership of SNC-Lavalin Major Project Inc., Dragados Canada Inc., and Flatiron Constructors Canada Limited)
- Designer: TYLI-IBT-SLI Joint Venture (JV of TYLin Canada Inc., Systra-International Bridge Technologies Canada Inc., and SNC-Lavalin)
- Owner Eng.: Arup Canada Inc.
- Independent Eng.: Stantec/ Ramboll
- Design Subconsultants: Akana (Cooper Zietz Engineers), Boundary Layer Wind Tunnel Laboratory at the University of Western Ontario, Doug Williams, Frieder Seible, Fugro Consultants, IFN Engineering, HLB (Illumination Arts), Karagozian & Case, MacDonald Architects, NC3D, Ross & Baruzzini, Tourney Consulting Group, WEST Consultants, West Wind Laboratory, WSP (MMM)

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Gracias!!

Credit: *@ThomasHeinser*