IABSE-JSCE CONFERENCE
Advances in Bridge Engineering -IV

Design and Construction of Sea Crossing Bridges

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Dacca Bangladesh
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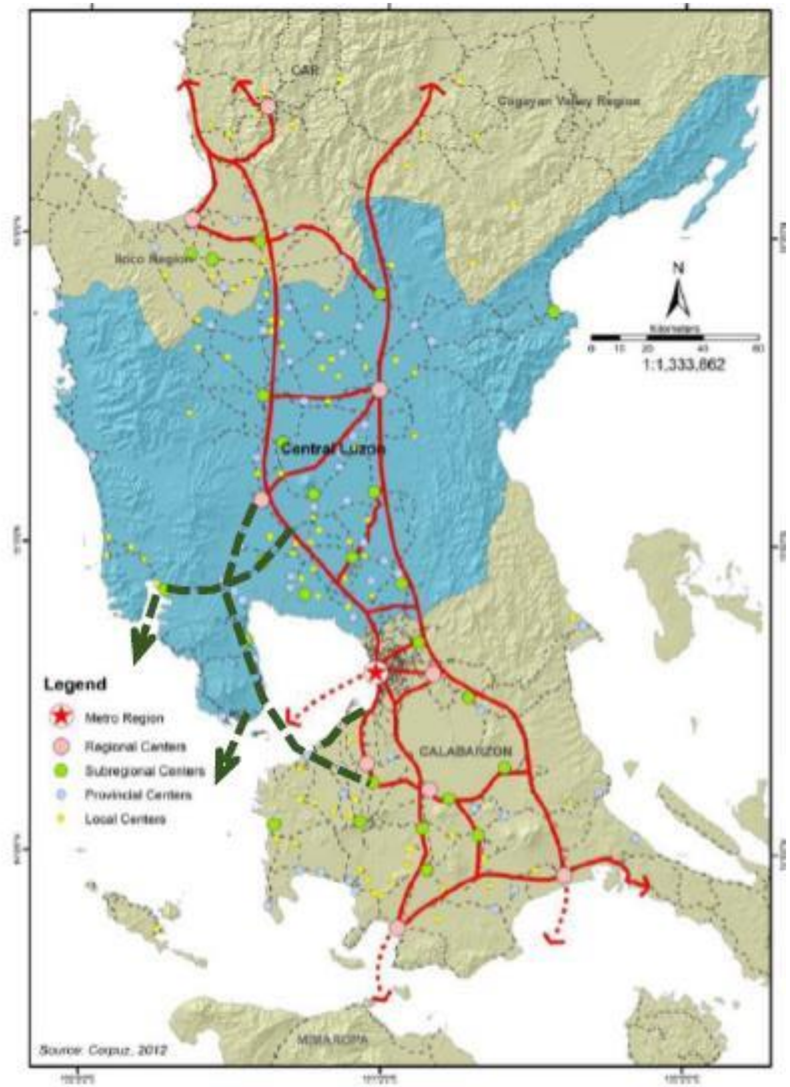
DESIGN OF SEA CROSSING BRIDGES

The form and function of bridges depend upon their location and environmental conditions, and as time is limited for this web based conference , I am going to describe just one bridge in Philippines for which we have very recently completed the Feasibility and Preliminary Design. The bridge is the:

BATAAN CAVITE INTERLINK BRIDGE

Objectives of Bataan-Cavite Interlink Bridge (BCIB) Project

- Provide an alternative loop road to ease traffic congestion in Metro Manila and, South Luzon and North Luzon gateway;
- Support development of seaports of Cavite and Bataan as premier international shipping gateway to the country;
- Provide opportunities for expansion outside Metro Manila for economic growth;
- Save time and lower the vehicle operating costs, improve profitability and marketability of goods and provide access to social services within the project proximity.
- Support development of the famous Corregidor Island as a tourist spot;



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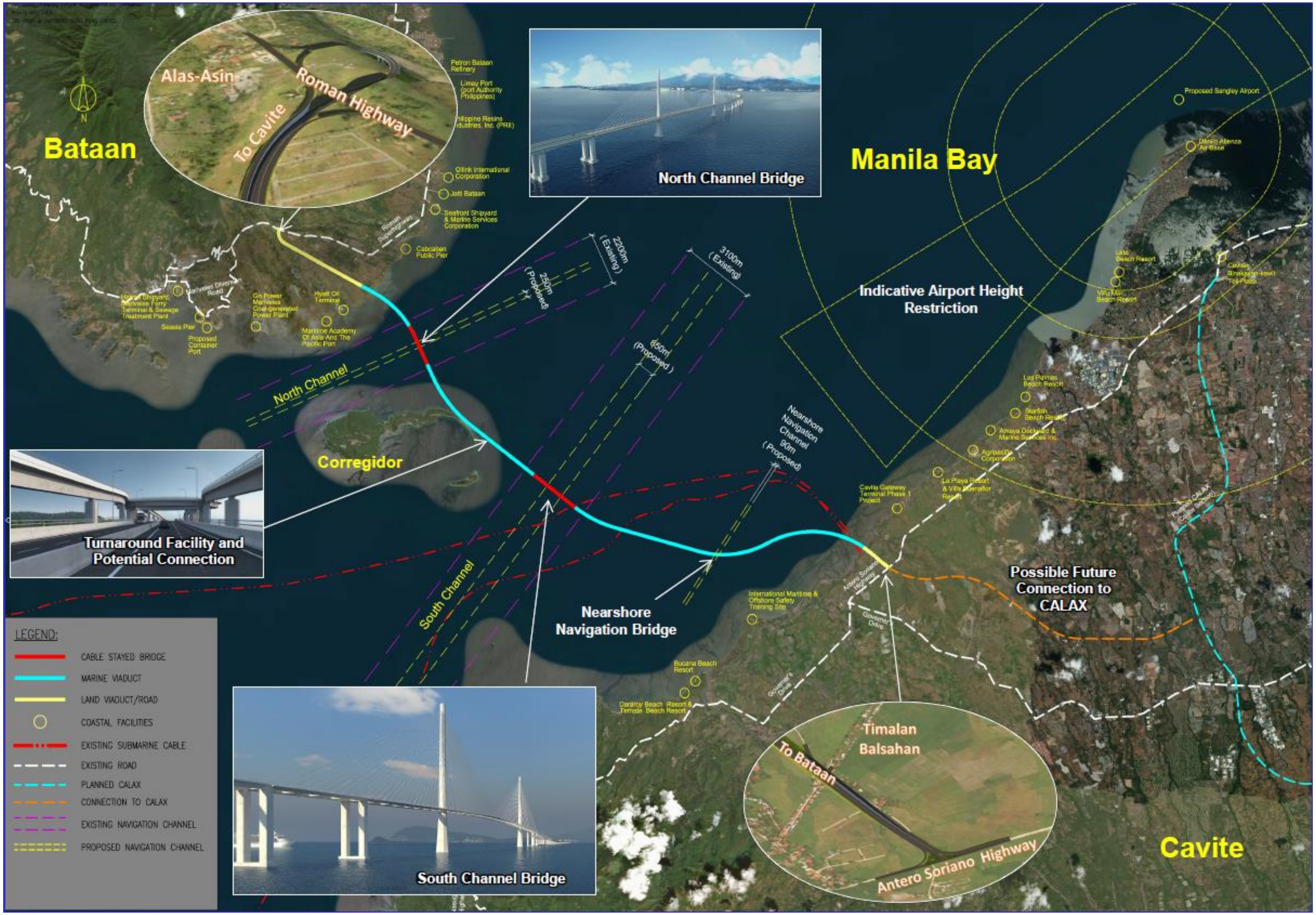
THE DESIGN OF THE BRIDGE HAS CATERED FOR EXTREME ENVIRONMENTAL CONDITIONS AND EVENTS SUCH AS

- 50m Deep Water
- Crossing of 2 major shipping channels
- Ship Impact from Large Vessels
- Typhoon Winds
- High Seismicity

Bataan-Cavite Interlink Bridge Alignment (25.8km sea+6.35km land)



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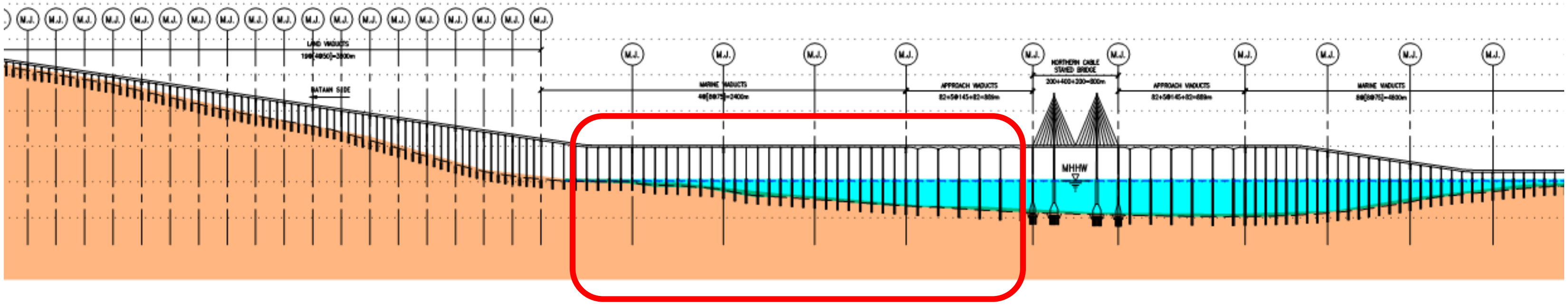
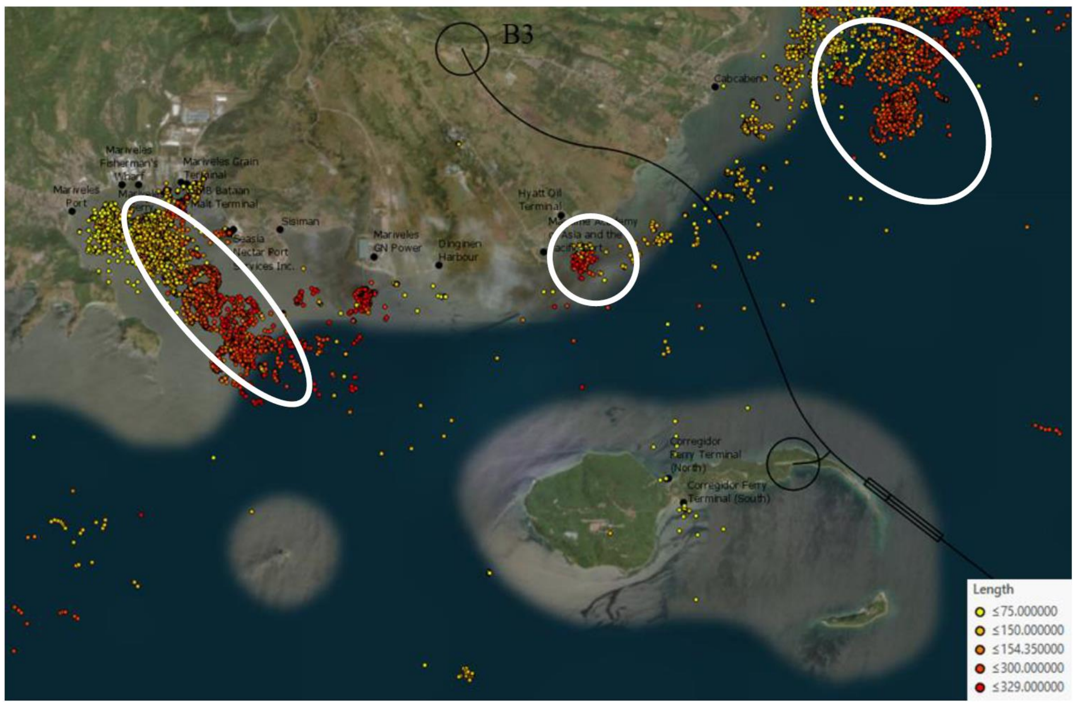
Bataan landing point



Alignment to avoid the existing marine facilities anchorage zones



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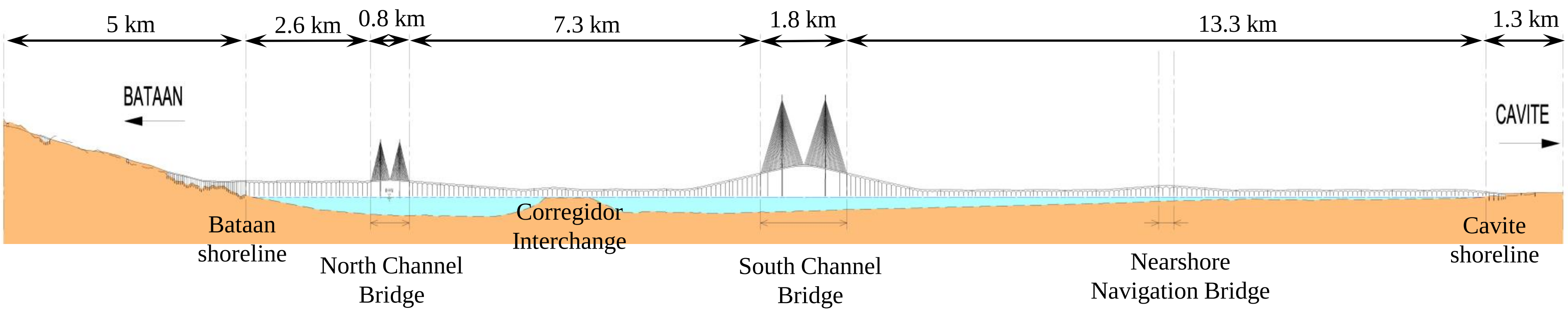
Overall Elevation



North Channel Bridge

South Channel Bridge


Bataan
Corregidor
North Channel Bridge
South Channel Bridge
To Cavite
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ROADS & BRIDGES
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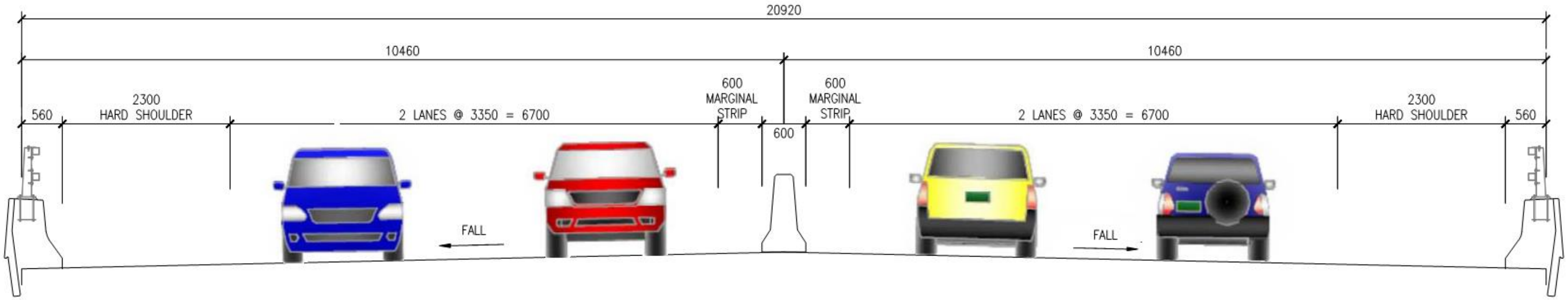
Functional Cross Section



Nearside hard shoulder (m)	Lane Width (m)	Farside marginal strip (m)	Carriageway width (m)	Total Bridge width (m)
2.3	3.35 x 2 lanes	0.6	9.6	20.92

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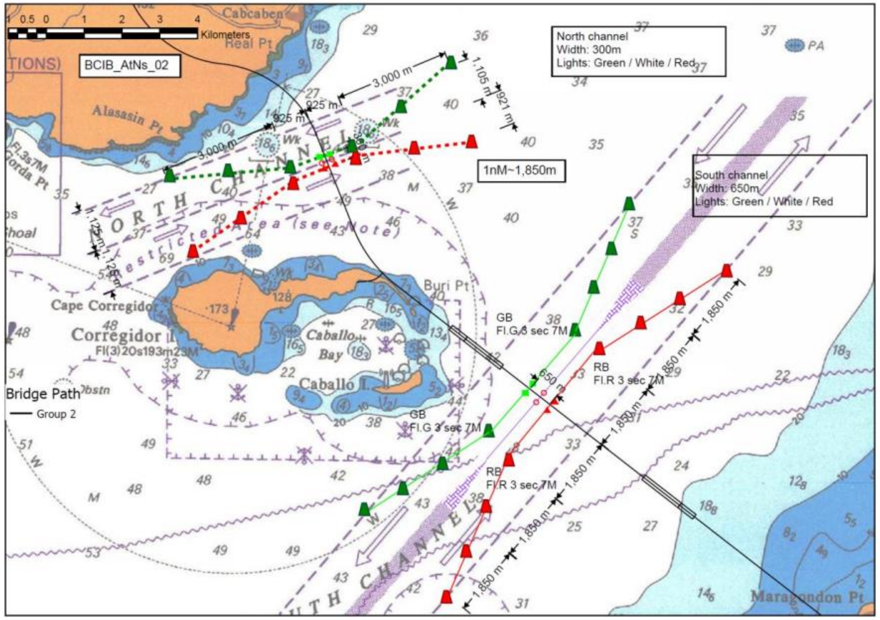
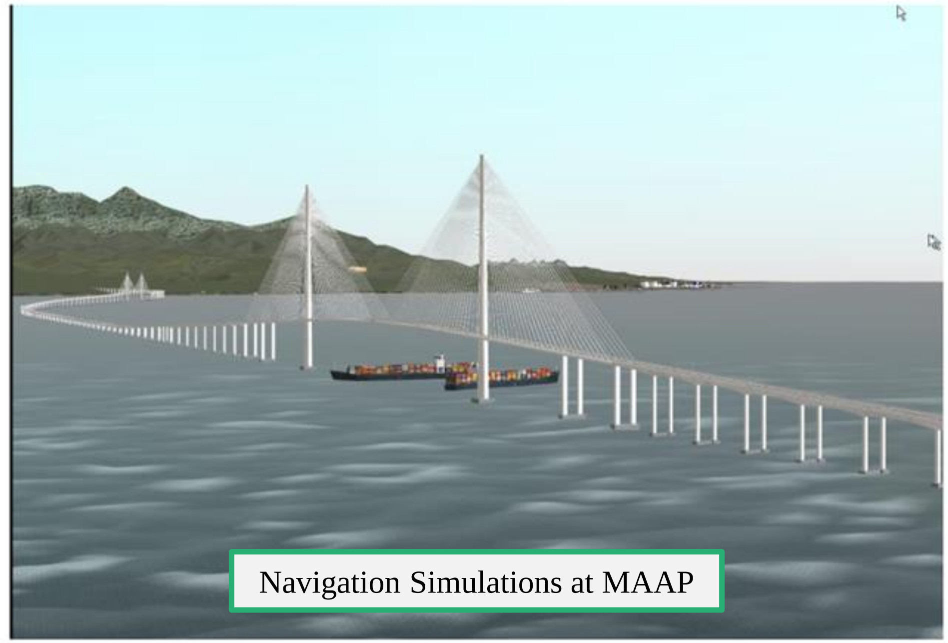
Navigation Bridges

Span and height clearance – Navigation Simulations





Location	Minimum Horizontal Clearance between obstructions	Marked Navigation Channel
South Channel	870m	750m (two-way)
North Channel	380m	300 (two-way)

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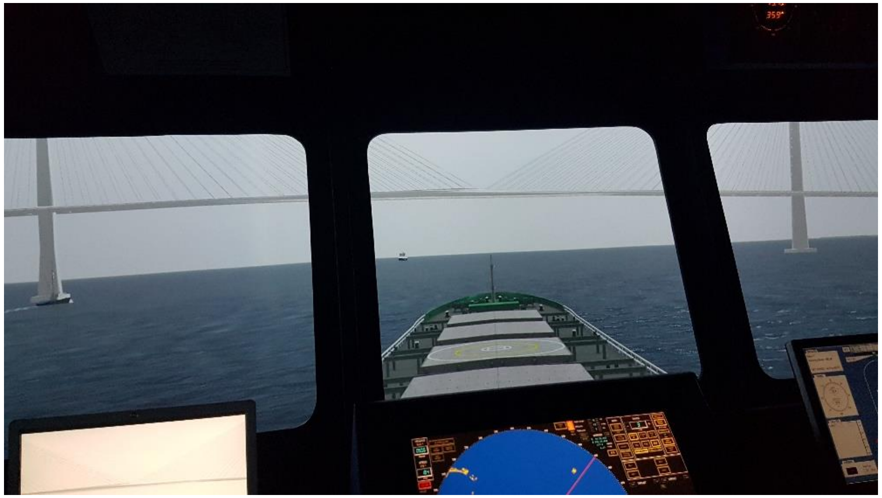
Span and height clearance – Navigation Simulations



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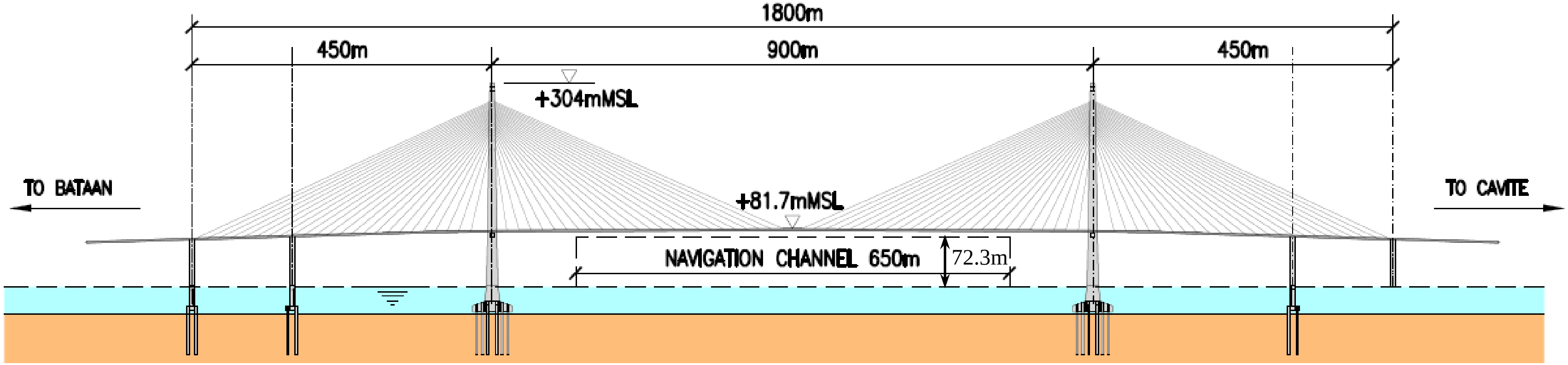
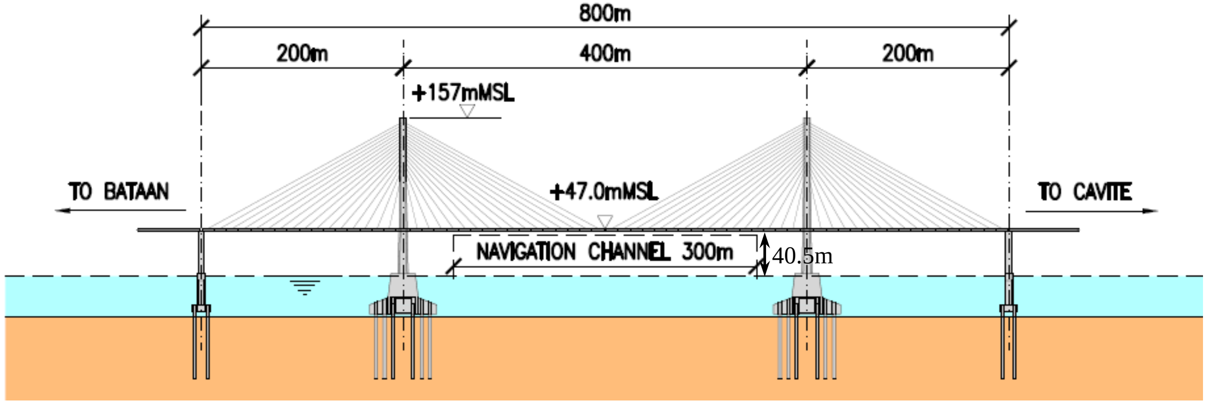
Span and Height Clearance



South Channel Bridge



North Channel Bridge

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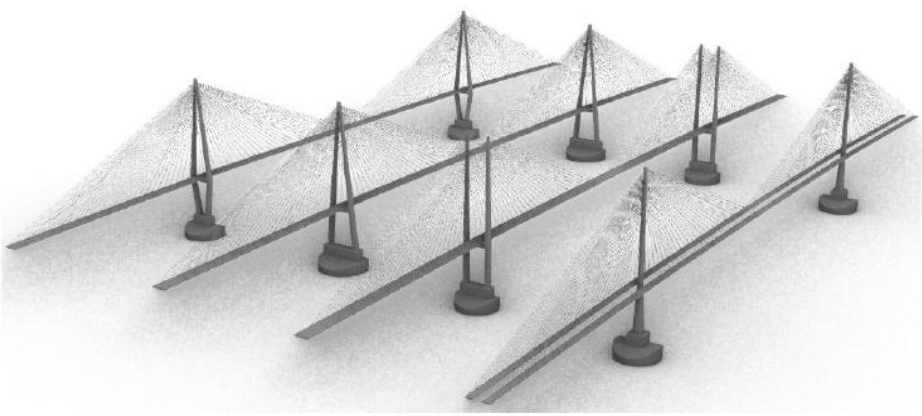
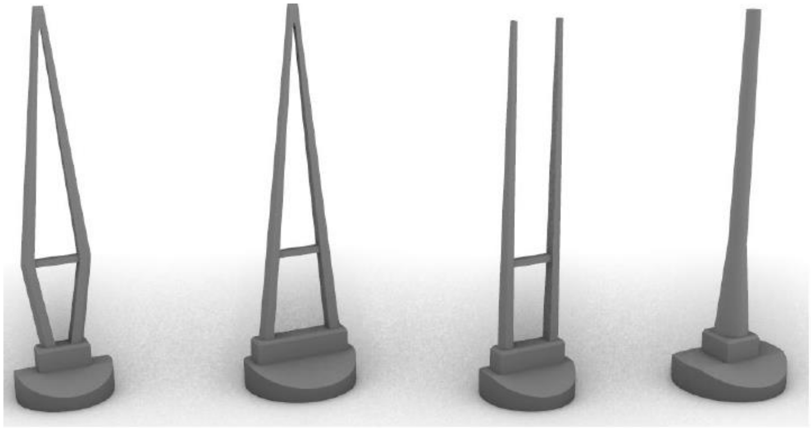
South Channel Bridge

Tower Option Study

- Towers are predominant visual features.
  - Four basic shapes - Diamond, A-frame, H-shaped, Monopole

- It was crucial to select a tower shape that would optimally satisfy the various requirements





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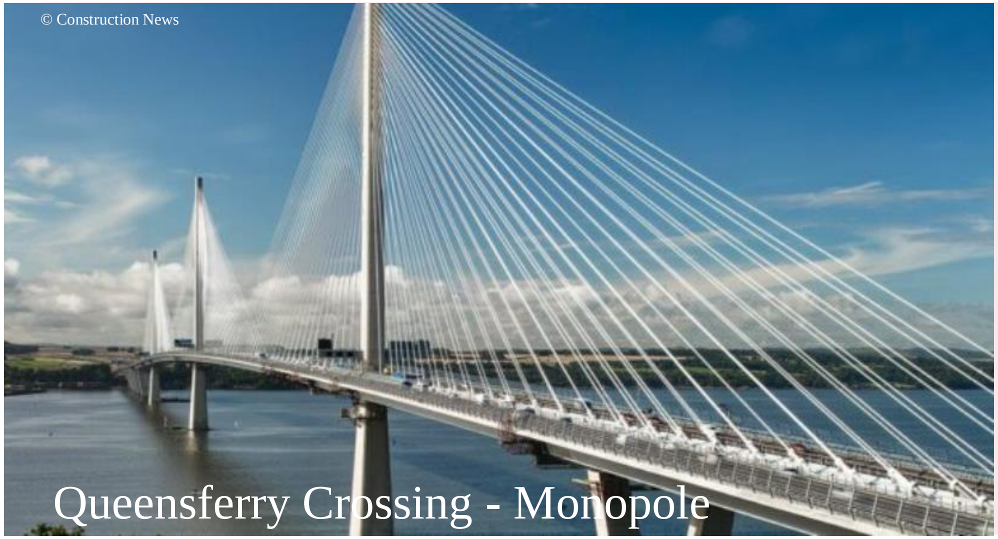
South Channel Bridge – Tower Option Study



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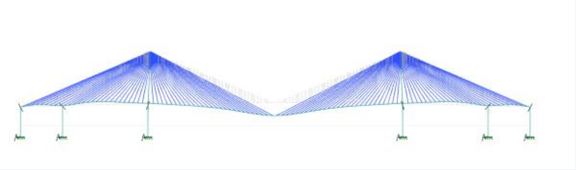
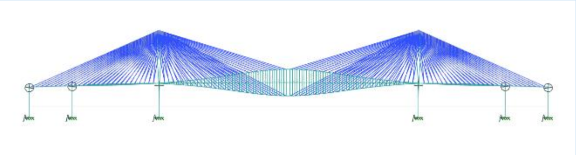
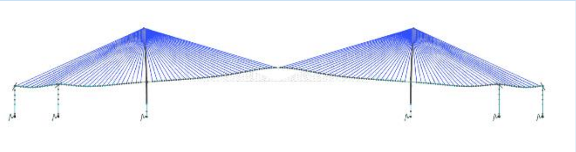
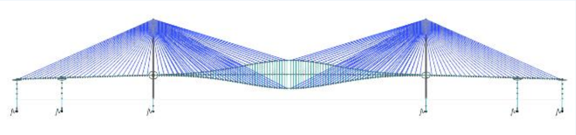
South Channel Bridge – Diamond vs Monopole

- Aerodynamic stability

Mode	Frequency [Hz]	Period [s]	Description	Image
Diamond Tower				
3	0.1839	5.437	1st vertical mode of deck	
13	0.5012	1.995	1st torsional mode of deck	
Monopole Tower				
4	0.1853	5.398	1st vertical mode of deck	
11	0.4564	2.191	1st torsional mode of deck	

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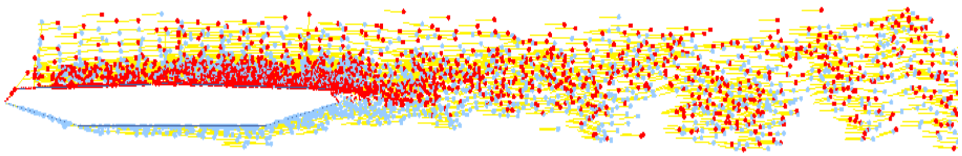
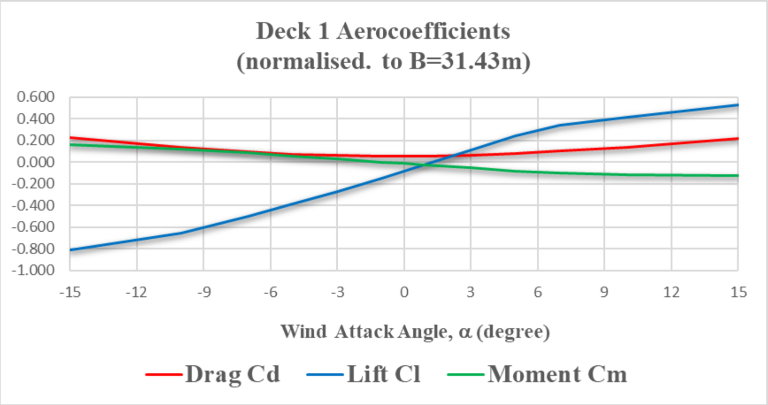
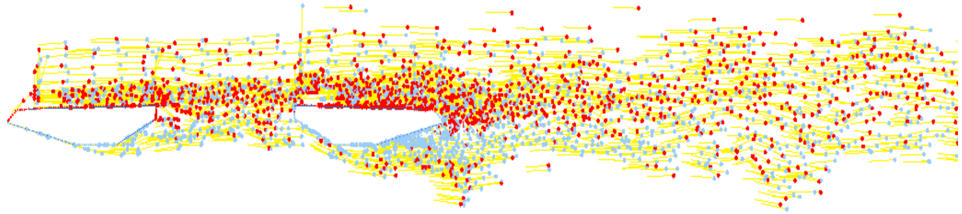
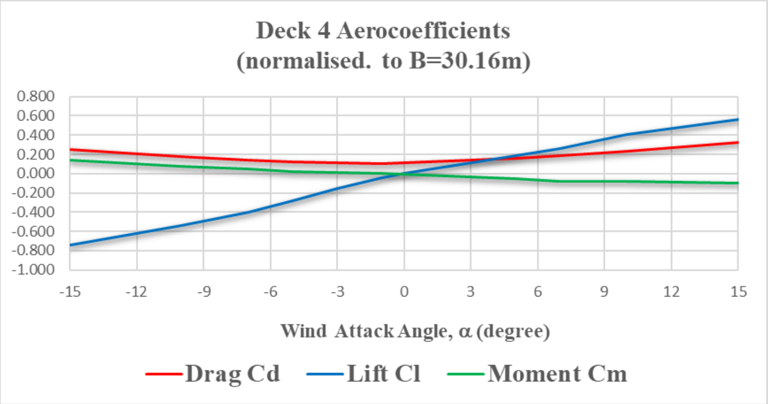
South Channel Bridge - split vs. single deck

- RMDVM Analysis









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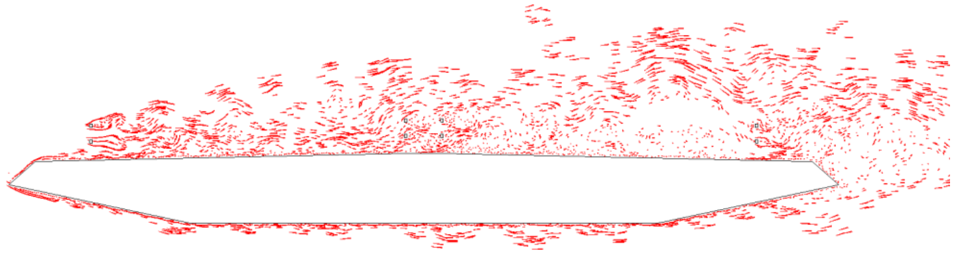
South Channel Bridge – Stability

- ArupDVM Analysis



- The deck section became unstable at 110m/s, in the in-service condition at 5 degrees nose-down attitude. This is more than 20% above the 10,000 year 10 minute mean wind speed at deck level, suggesting adequate performance.

- However a monopole tower with split steel boxes would be more economical and easier to build and hence was taken forward for preliminary design.

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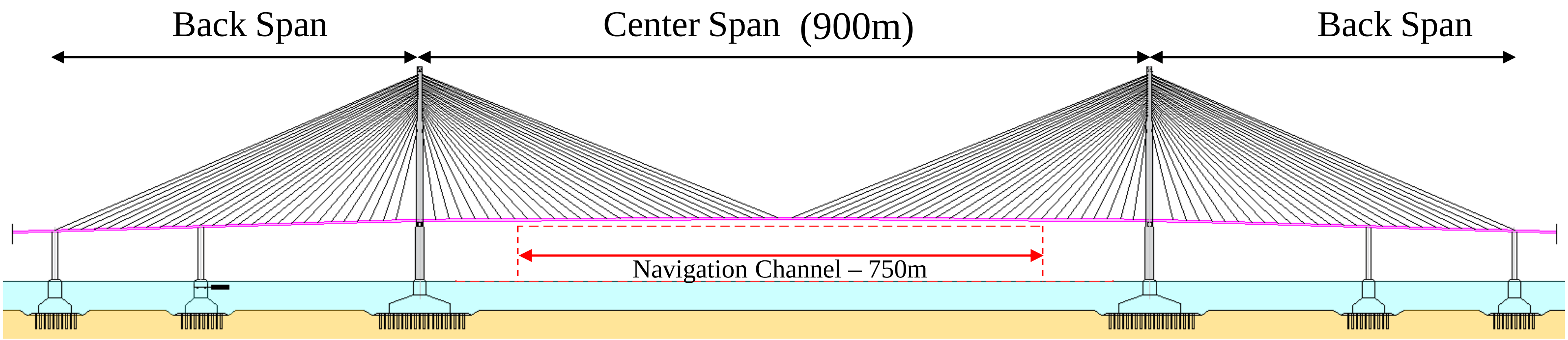
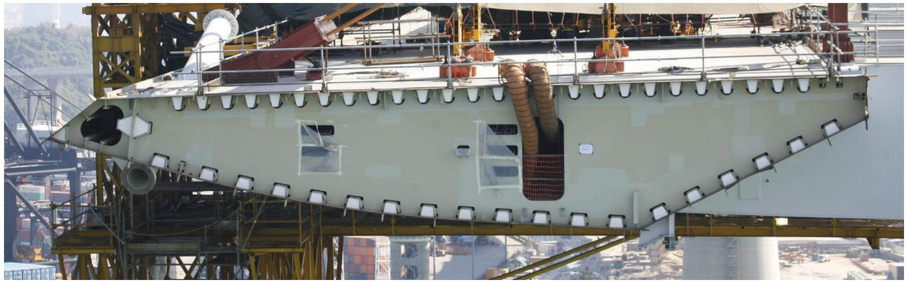
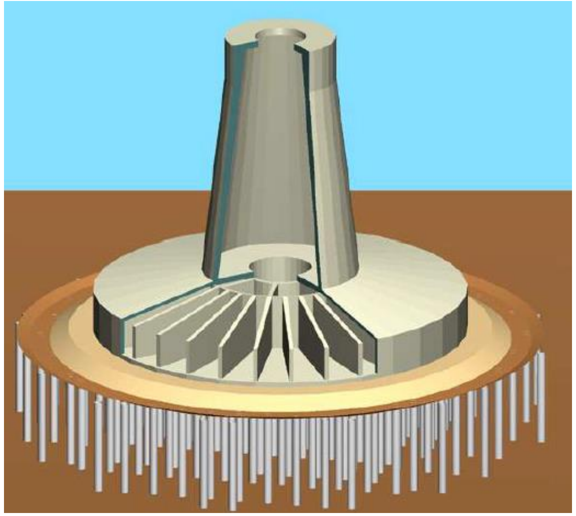
South Channel Bridge



South Channel Bridge – Elevation



steel orthotropic deck



Typical Caisson

Concrete Tower

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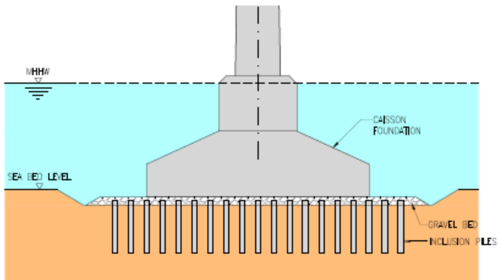
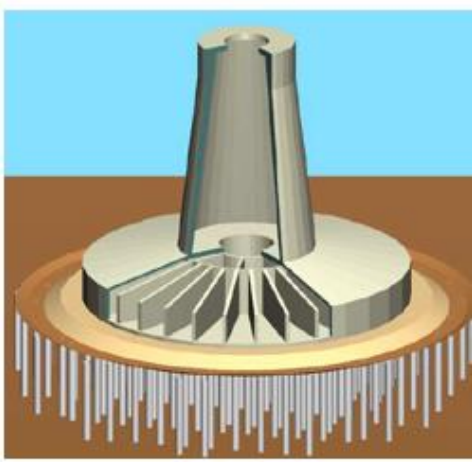
Caisson vs Submerged Pile Cap

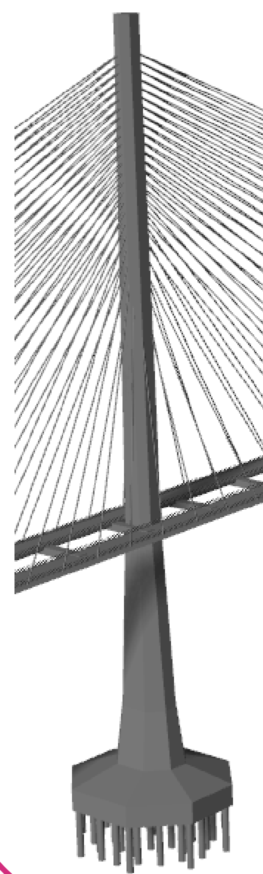
CAISSON WITH INCLUSION PILES

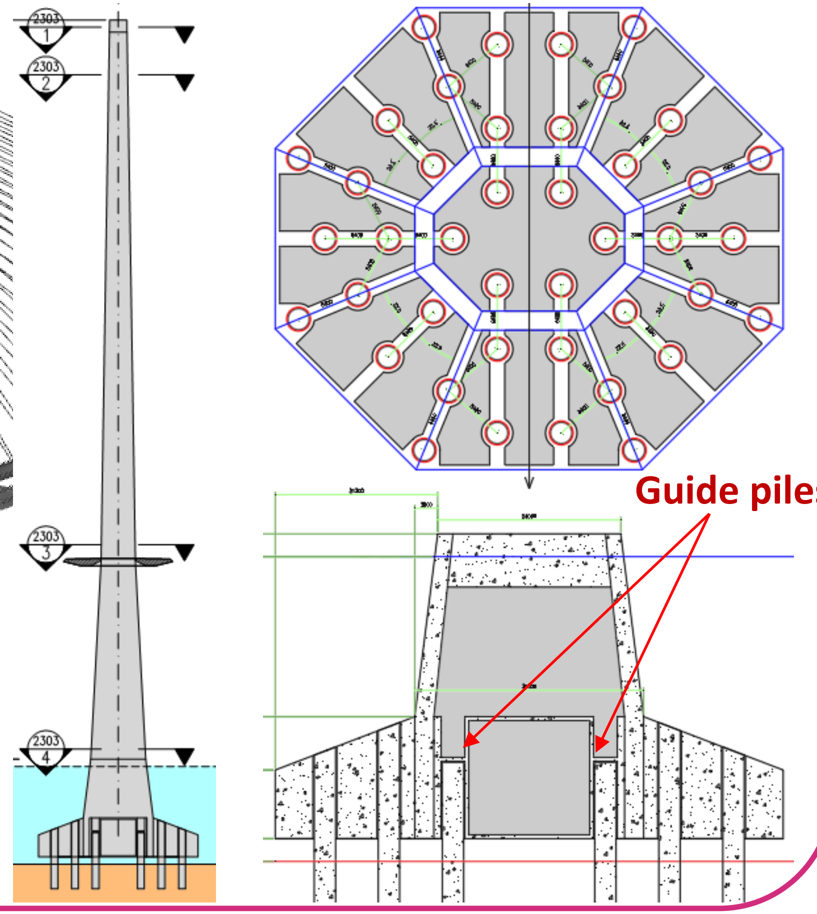




Typical Caisson

SUBMERGED PILE CAP WITH BORED PILES





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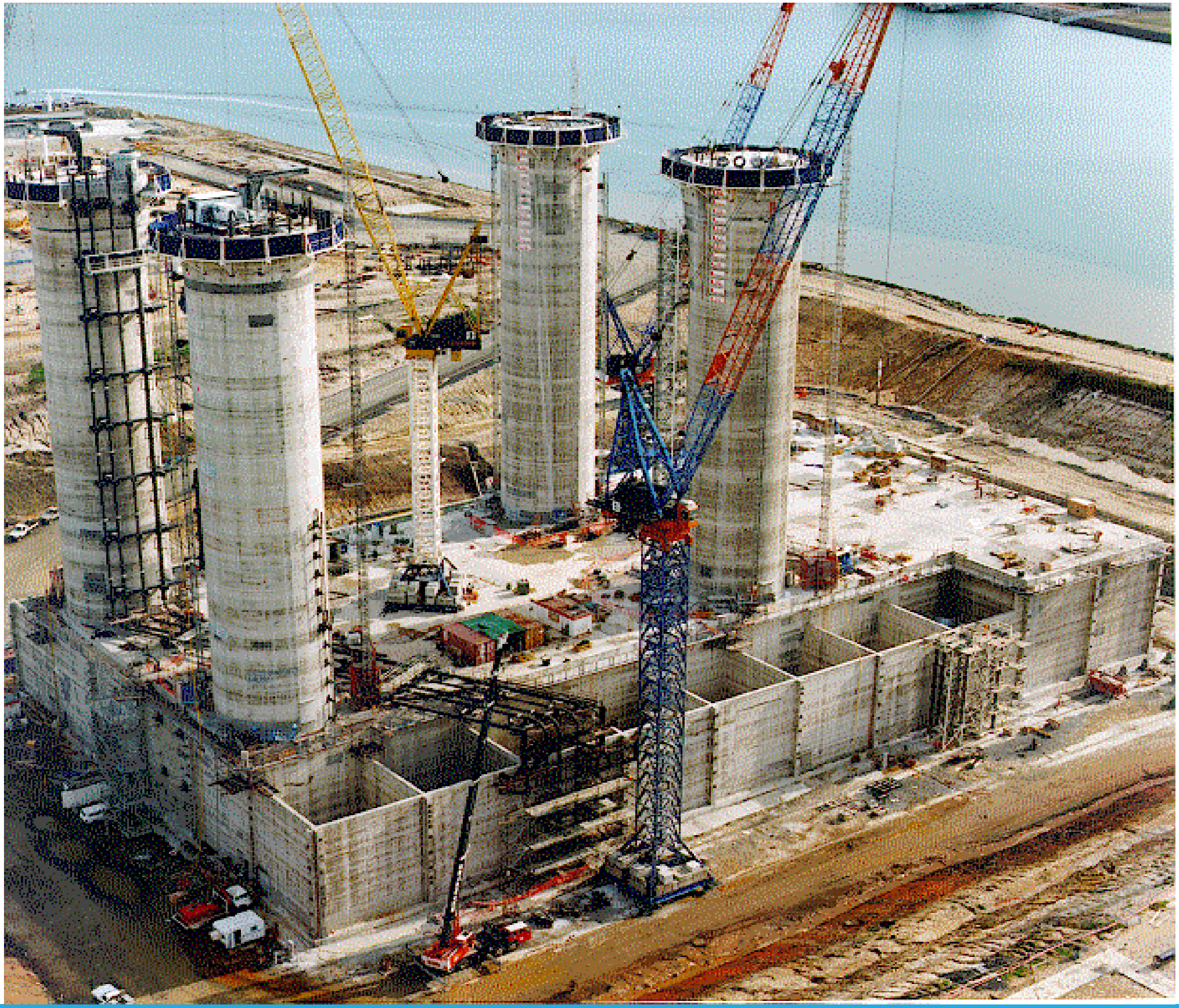
Pylon Caissons complete in Malmö Harbour dry dock (March 1997)

Malampaya Concrete Gravity Structure



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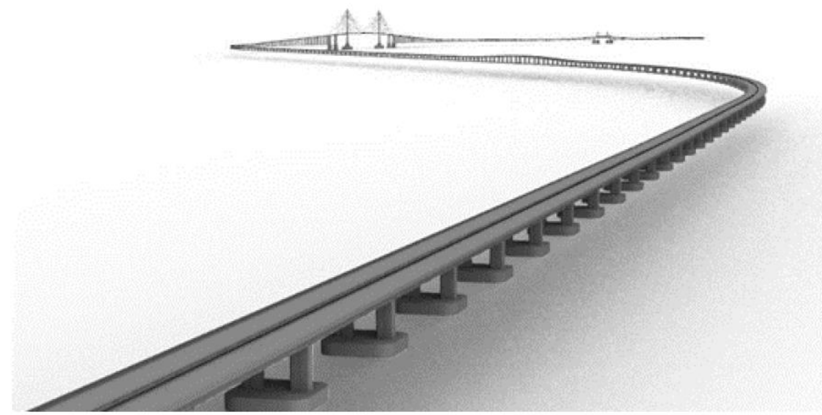
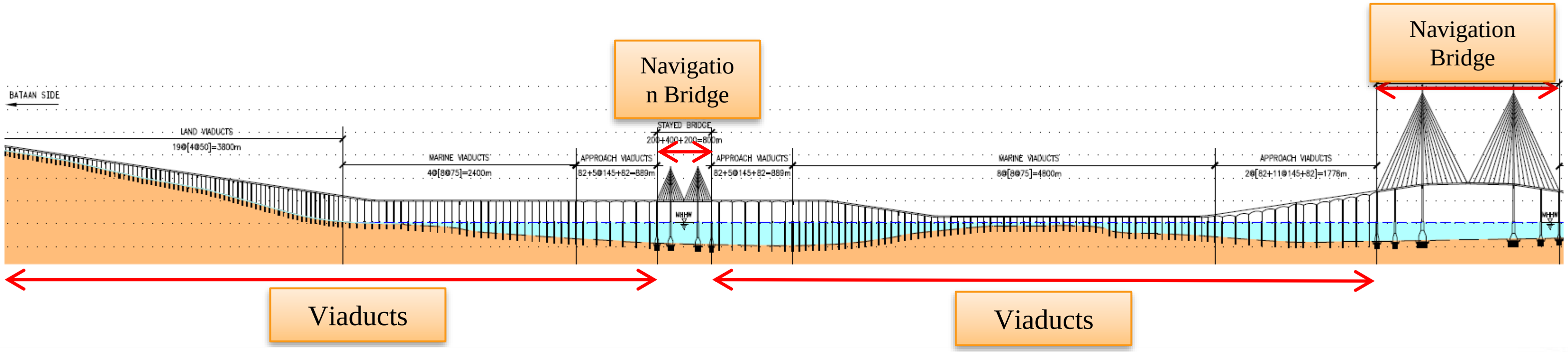
Marine Viaducts

Marine Viaduct Design

Varying water depth, 0 – 50m
Varying deck height, 15 – 70m
Varying soil conditions





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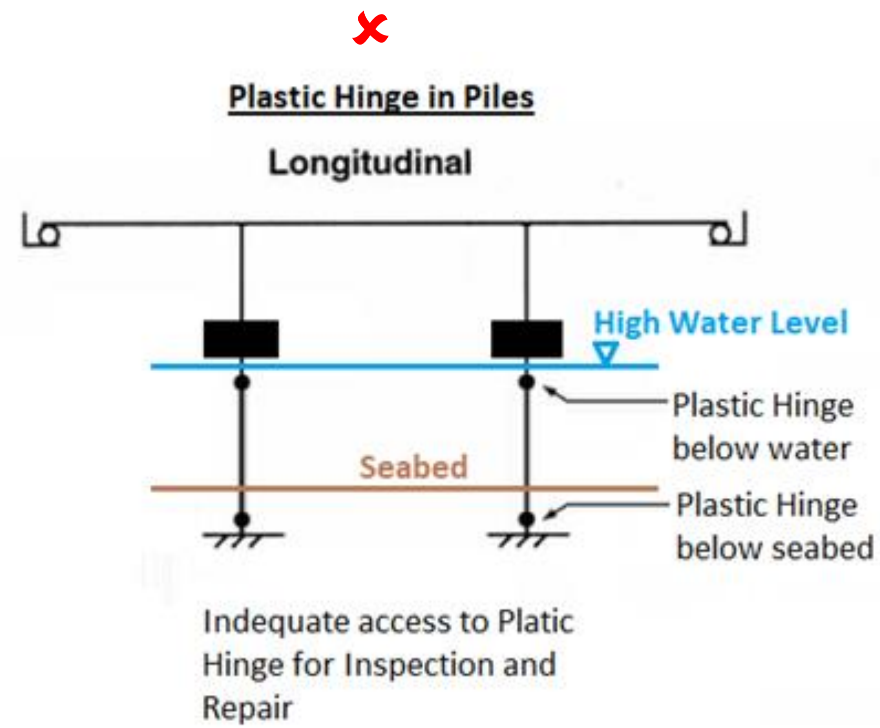
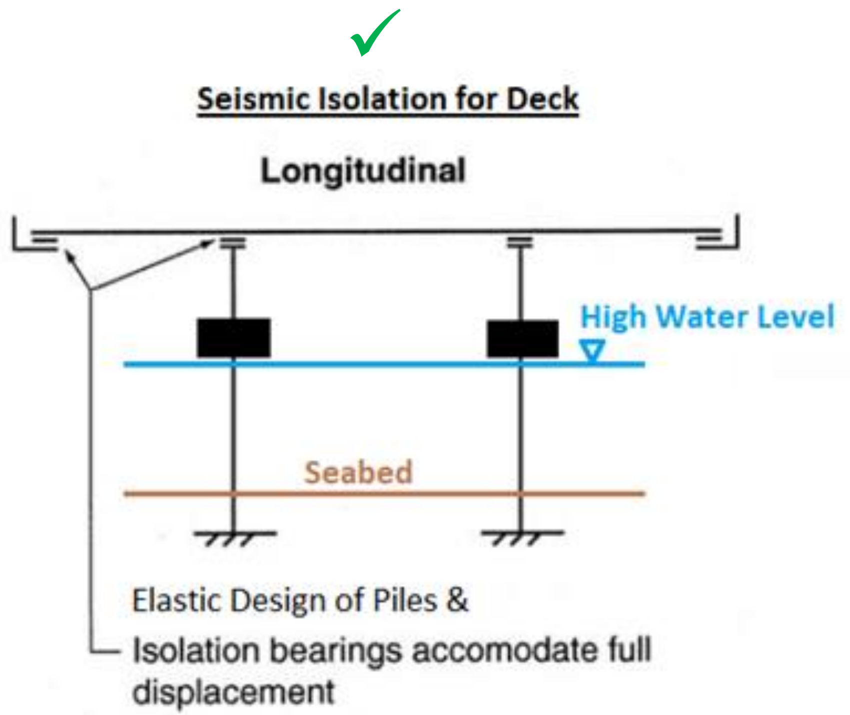
Articulation

- Seismic isolation using Friction Pendulum Bearings is proposed





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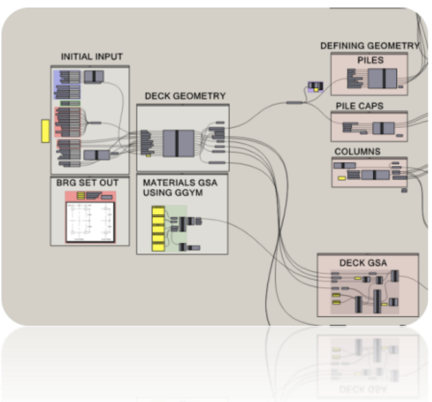
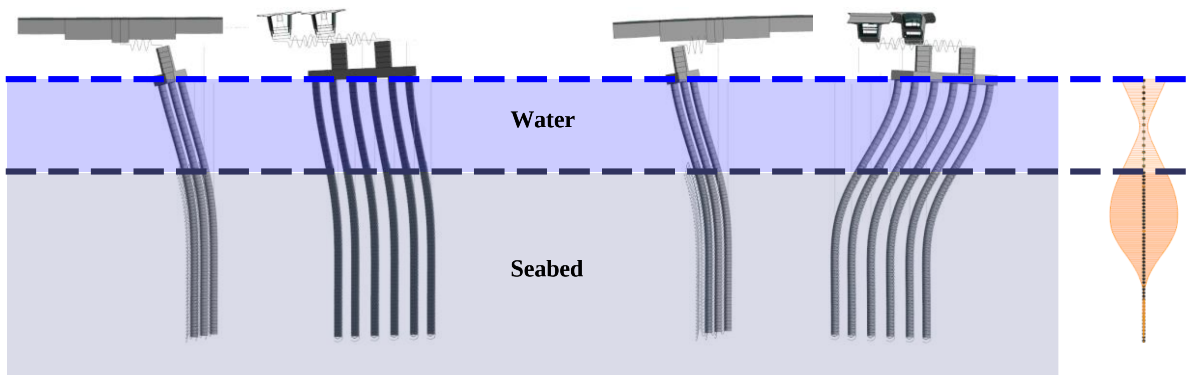
Overall Optimisation Study

- **Foundation**
  - Bored piles
  - Driven steel pipes
- **Deck type**
  - Composite
  - concrete
- **Span length**
  - 50m
  - 75m
  - 100m
  - 145m
- **Seismic Design**
  - Plastic hinging (Force based approach)
  - Plastic hinging (displacement based)
  - Friction pendulum bearing

Grasshopper Script ⟷ Parametric GSA models

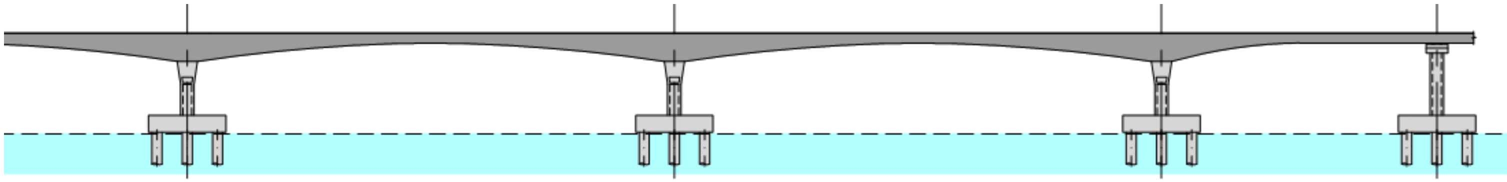




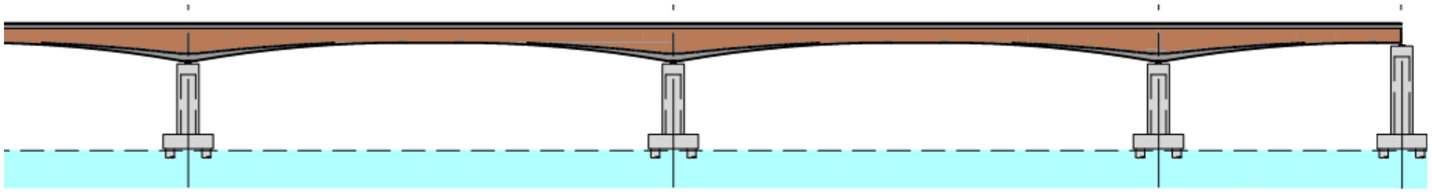
Deck Vibration Mode (Long & Trans) **Pile Vibration Mode (Long and Trans)** **Typical BM**

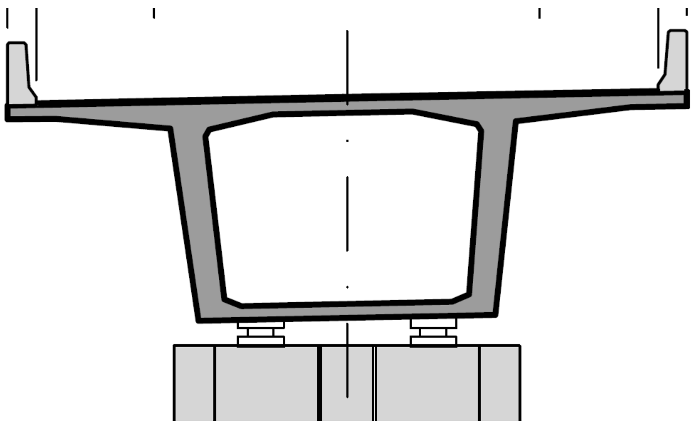
Deck Options – Concrete vs Composite

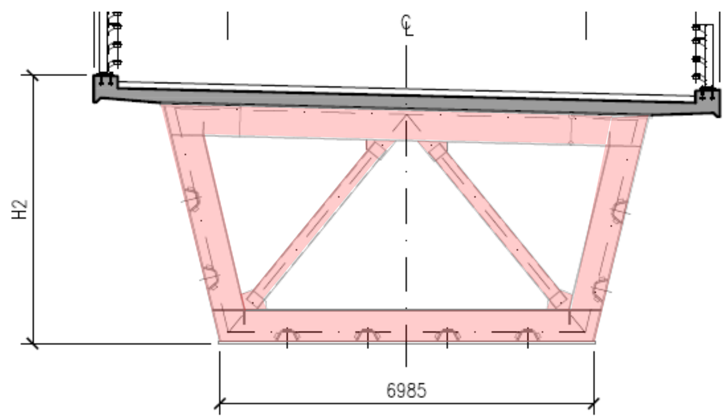
Concrete deck



Steel-concrete composite deck



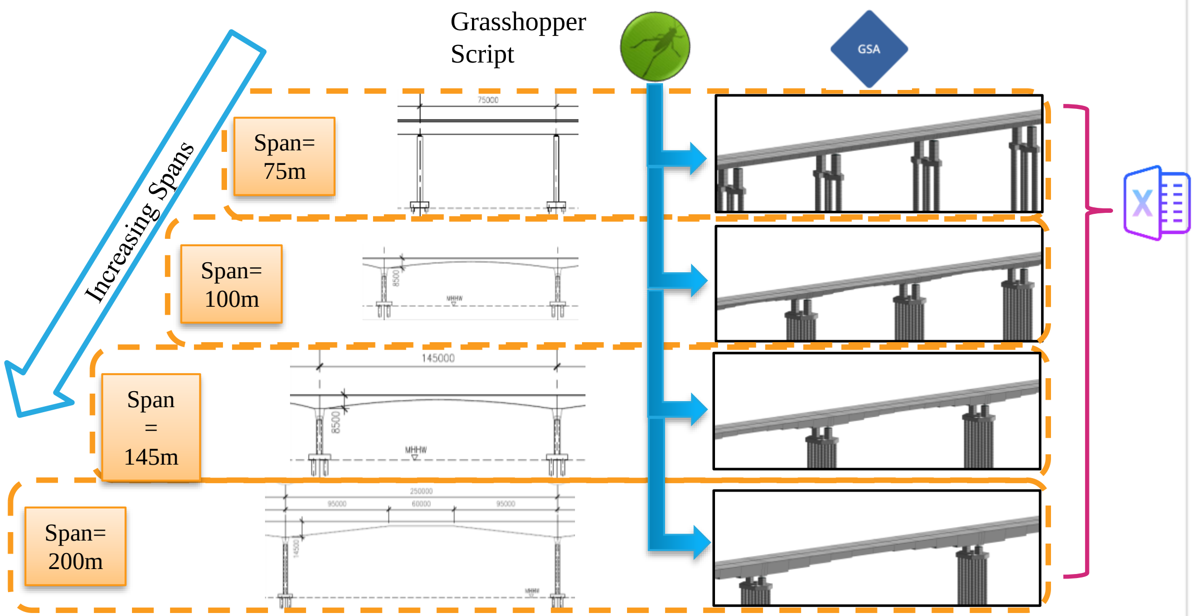




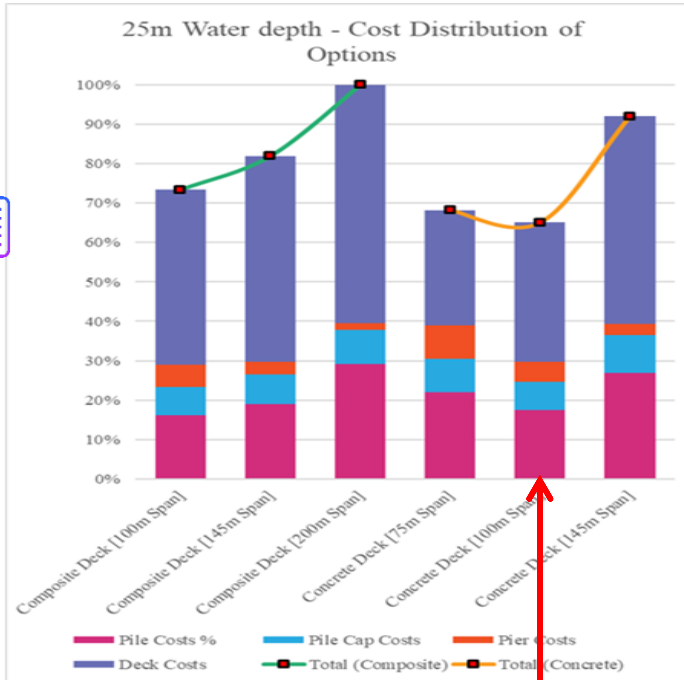
Concrete deck

Steel-concrete composite deck

Overall Optimisation Study



Optimization study



Cost Comparison

Conclusion – 100m concrete deck spans most economical

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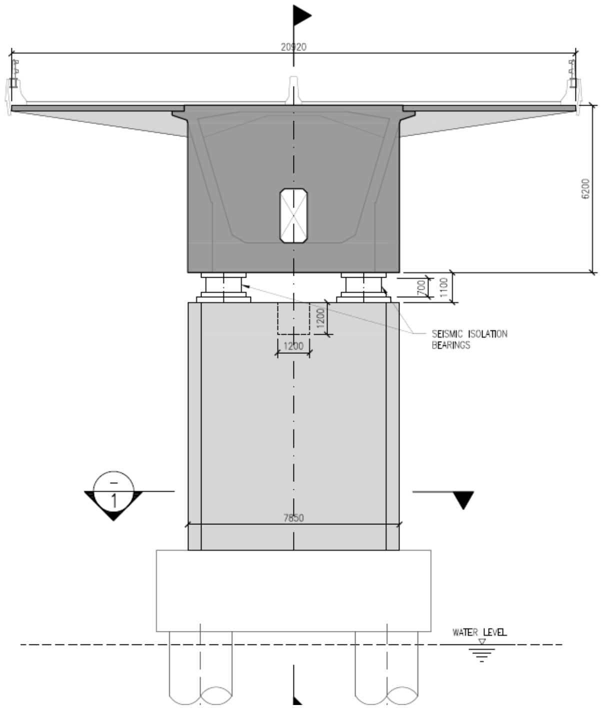
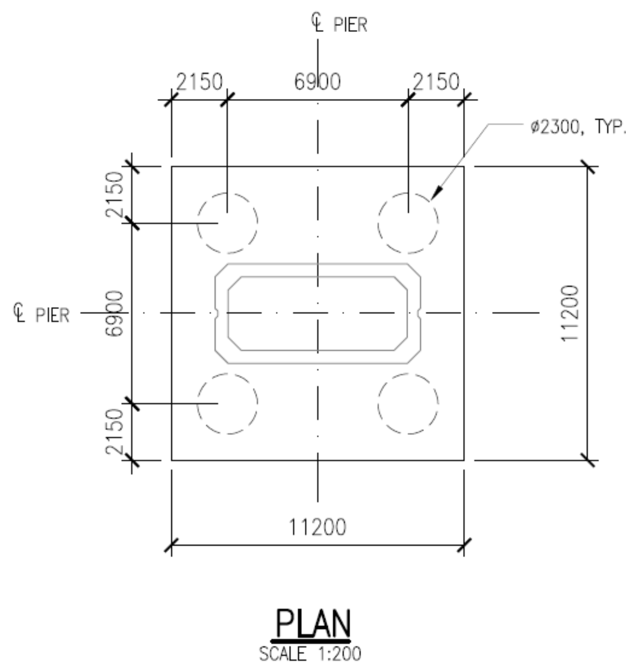
Pile Cap and Pier Column

- Pile Cap mass found to have very significant impact on seismic design of foundation
- Single column and compact Pile cap proposed for FS stage





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Pier shaft erected by Svanen - Oresund

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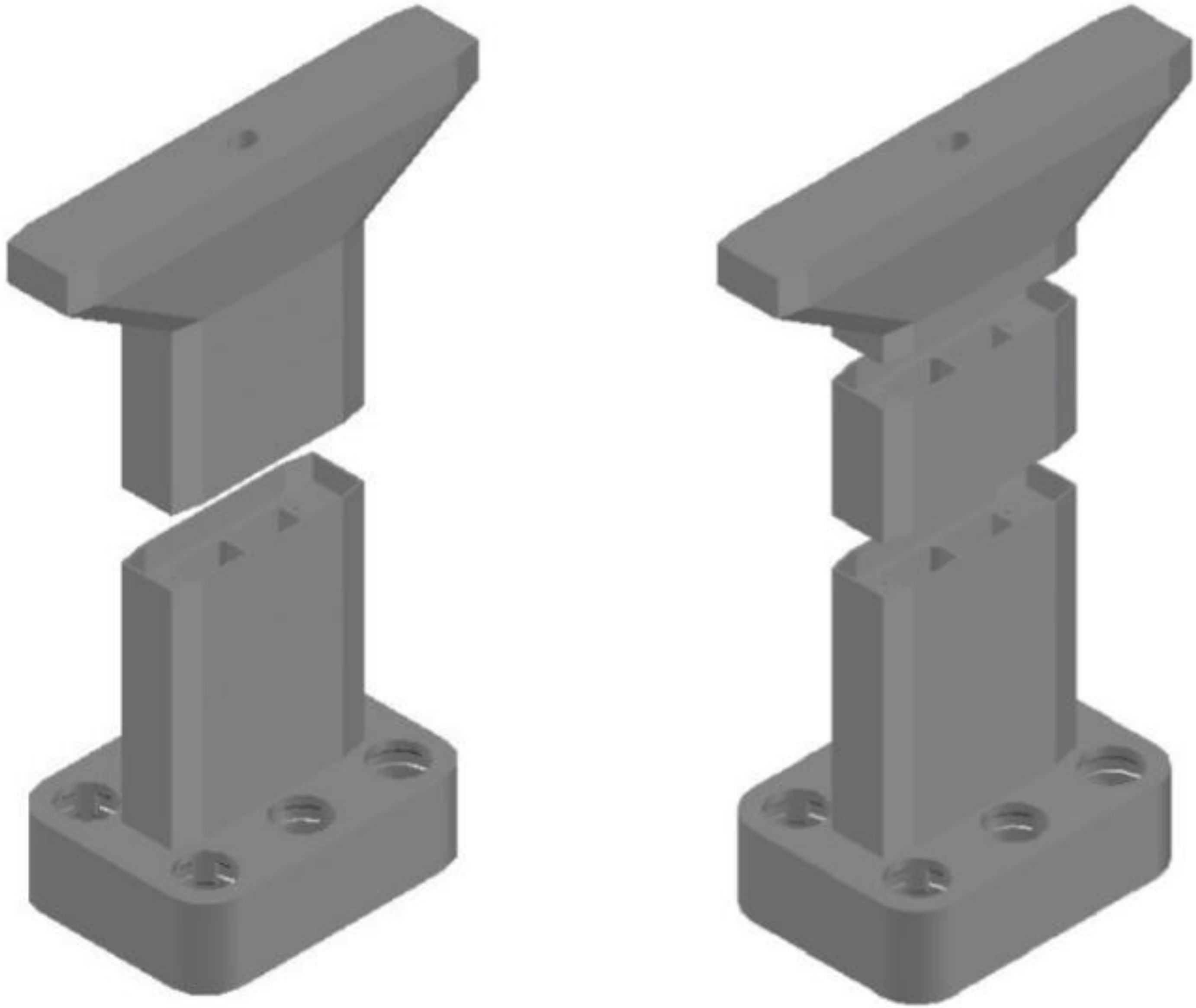

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Deck- Construction Method – Crane Type 3 -Svanen heavy lift vessel

Construction of the Confederation Bridge, Canada

Crane	
Hoisting capacity	8,700 t
Hoisting height above main deck	76 m
Hoisting speed at max. load	0.4 m/min

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140m Last Span Installation with Svanen

HKZMB Float out and installation of precast piers

Deck Construction Methods

<u>HZMB Main Bridge</u>
Full span steel box girder weight = 1600 tons
Lifting capacity of floating crane is 2600.

Deck Construction Methods

<u>HZMB Main Bridge</u>
Full span steel box girder weight = 3,500 tons
Lifting capacity of floating crane is 4000 tons.

CONCLUSIONS

Long span and long sea crossing bridges can be built in extreme environmental conditions such as deep water, ship impact, high winds and high seismicity

For fast and economic construction large off-shore prefabricated foundation and deck units erected by large floating equipment is necessary

Construction with robots will be likely in the future

Bridges with composite and/or high strength materials and replaceable parts will very likely be used in the future

Drones for inspection and rehabilitation works will likely be commonplace in the future

BUT THERE WILL ALWAYS BE A NEED FOR DESIGNERS WHO NEED TO TAKE INTO CONSIDERATION ENVIRONMENTAL AND CULTURAL ASPECTS, CLIENT'S BUDGET, AESTHETICS AND APPROPRIATE CONSTRUCTION TECHNIQUES TO DESIGN A BRIDGE THAT WILL BEST COMBINE FORM AND FUNCTION FOR THE PARTICULAR SITE

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THANK YOU