Dansk Ståldag 2012

Composite Bridges

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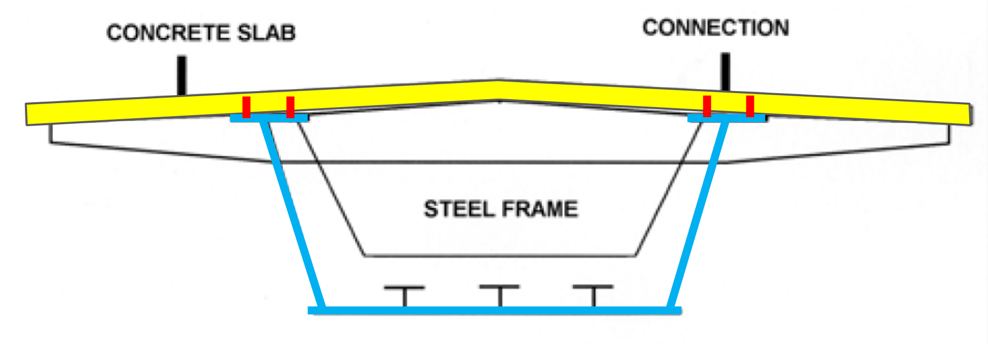
Steel-concrete composite decks

- Components:
  1. Steel frame
  2. Concrete slab
  3. Connectors



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Material properties

		Steel	Concrete
E-modulus	[MPa]	210000	Short:25000-45000 Long:10000-25000
Weight	[kN/m³]	77	25
Compressive strength	[MPa]	÷ 250-550 tends to buckle	+ 30-100
Tensile strength	[MPa]	+ 250-550	÷ Small tends to crack

› Exploitation of the different properties of steel and concrete make composite construction economic

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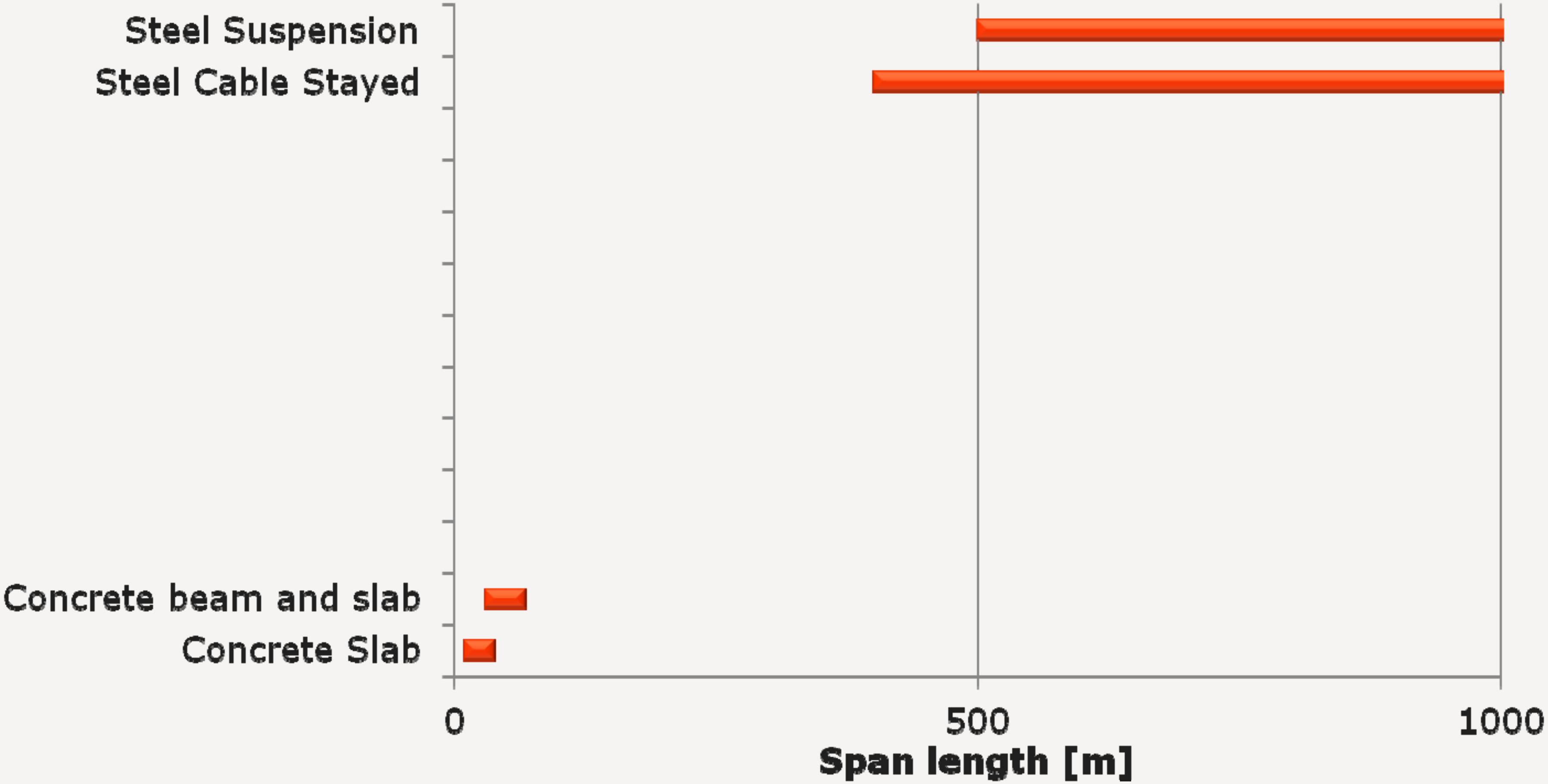
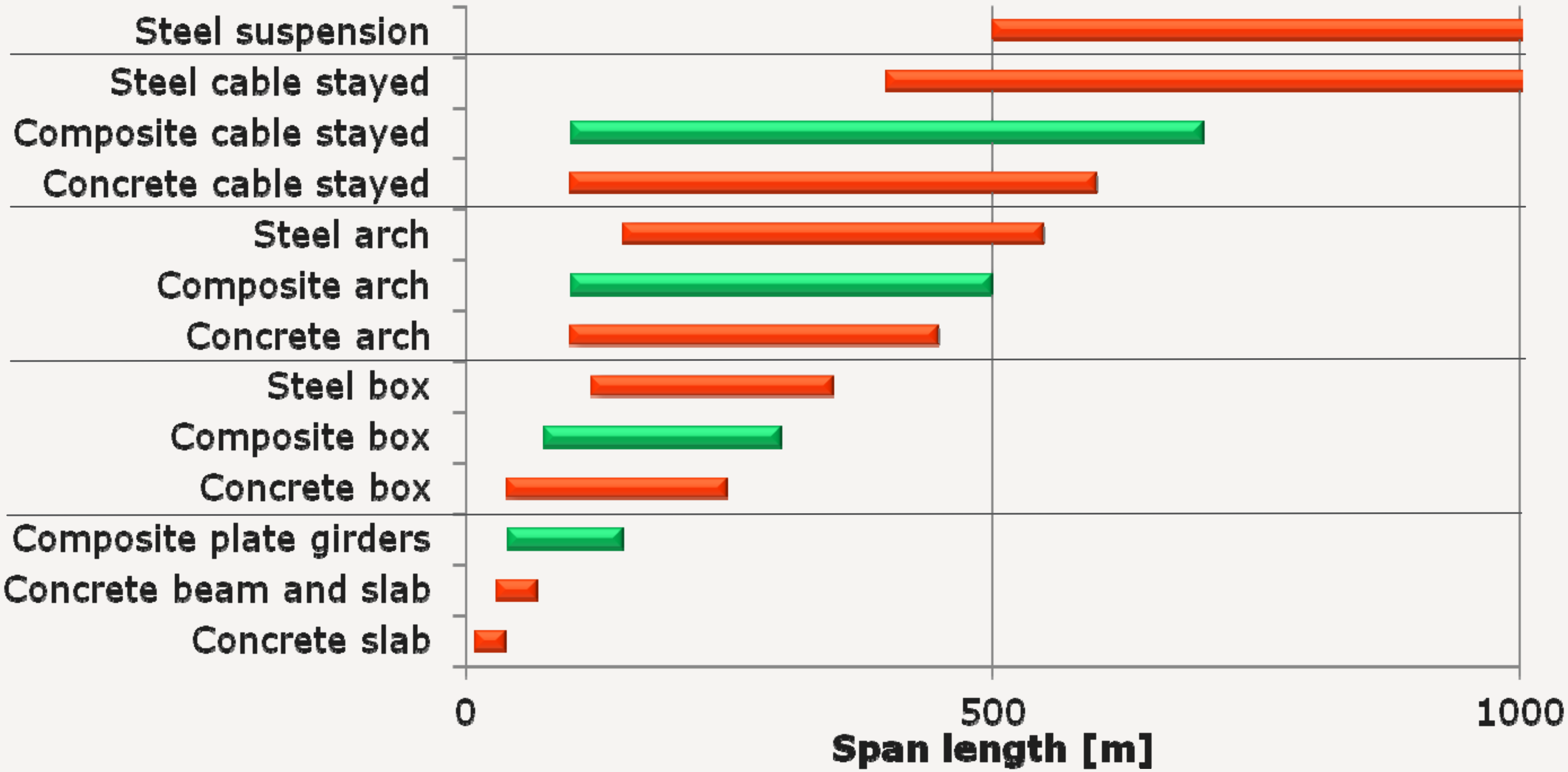
Bridge types for various span lengths



Bridge types for various span lengths



History

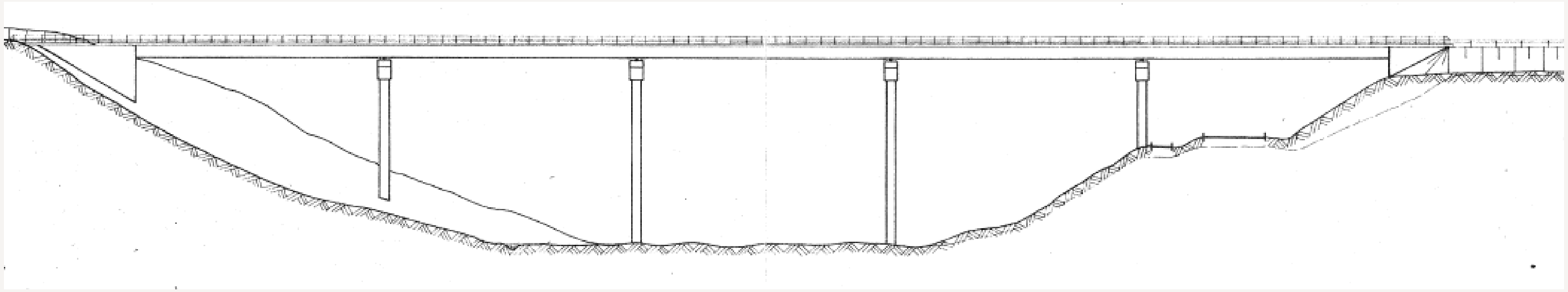
- First examples back to 1920's
- Became more common in 1970's due to new construction techniques and new design codes
- Extend of composite bridges very different between countries
- Not very much used in Denmark – probably mainly due to tradition, a large concrete industry and maintenance issues

Composite bridges in Denmark

Egernsundsbroen

Elbodalen

Hylkedalsbroen



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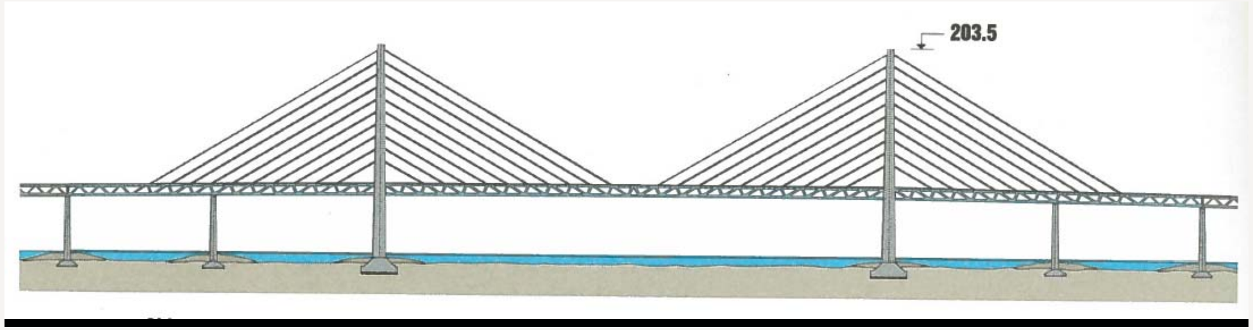
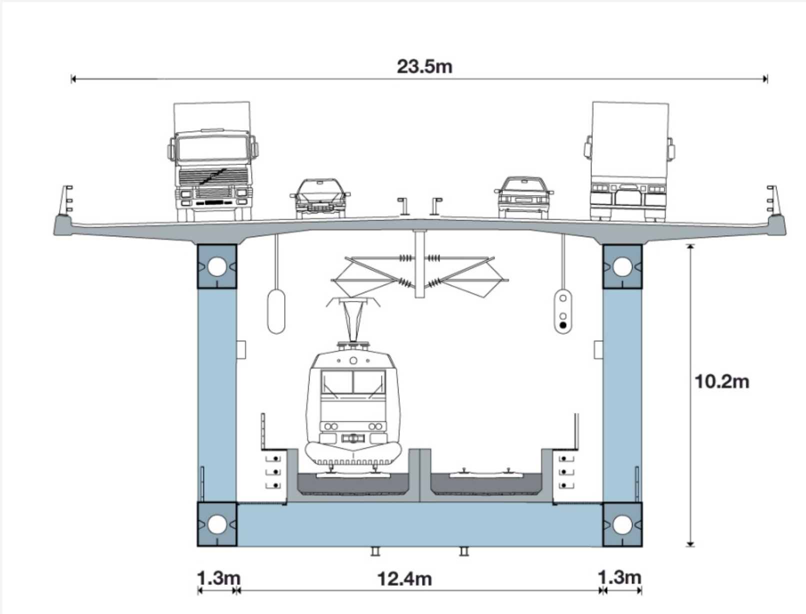
Composite bridges in Denmark

› Øresundsbron





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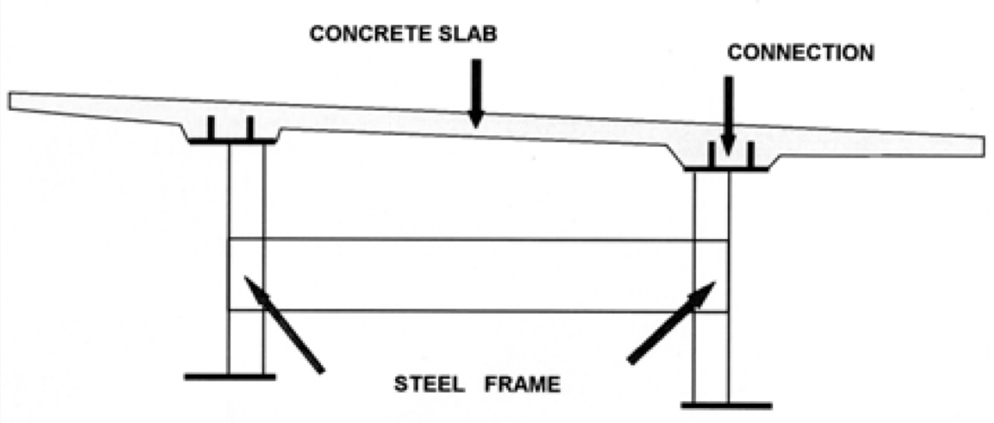
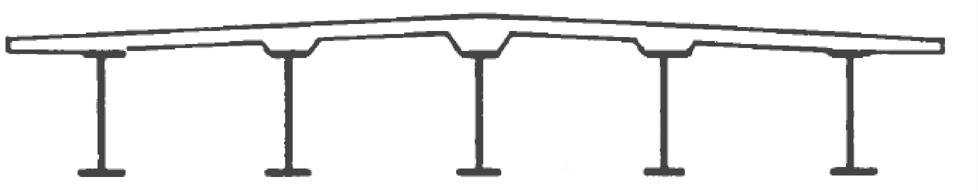
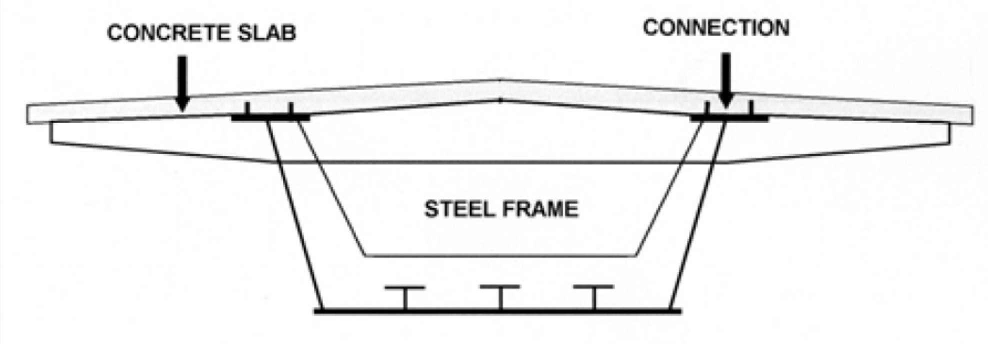
Girder types – steel frame

› I-girder sections
› Box girder







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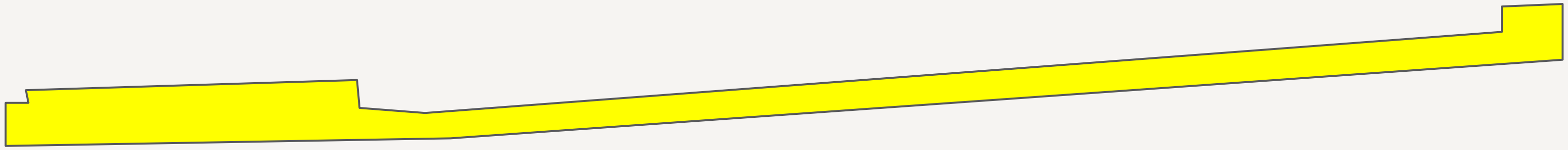
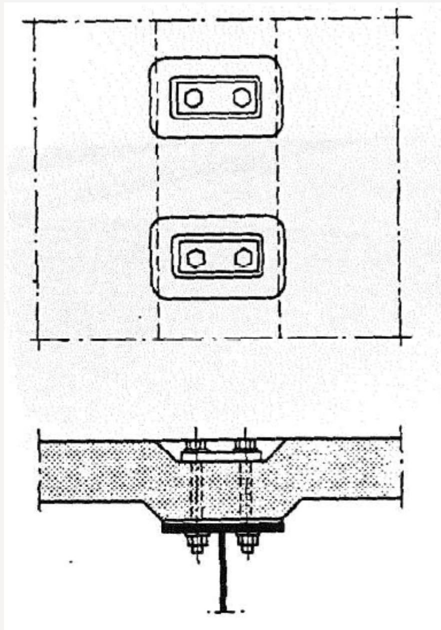
Girder types – concrete slab



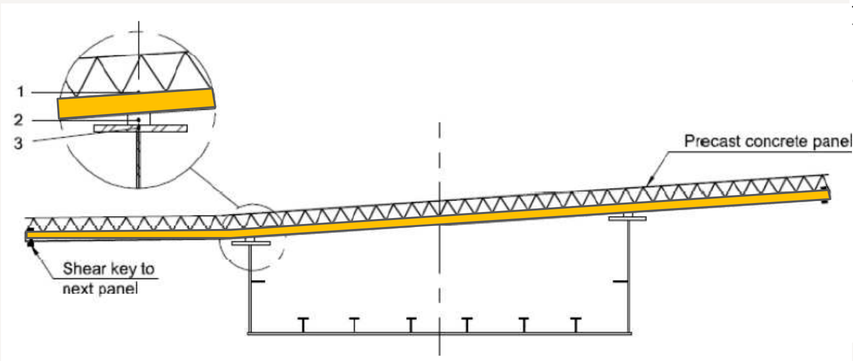


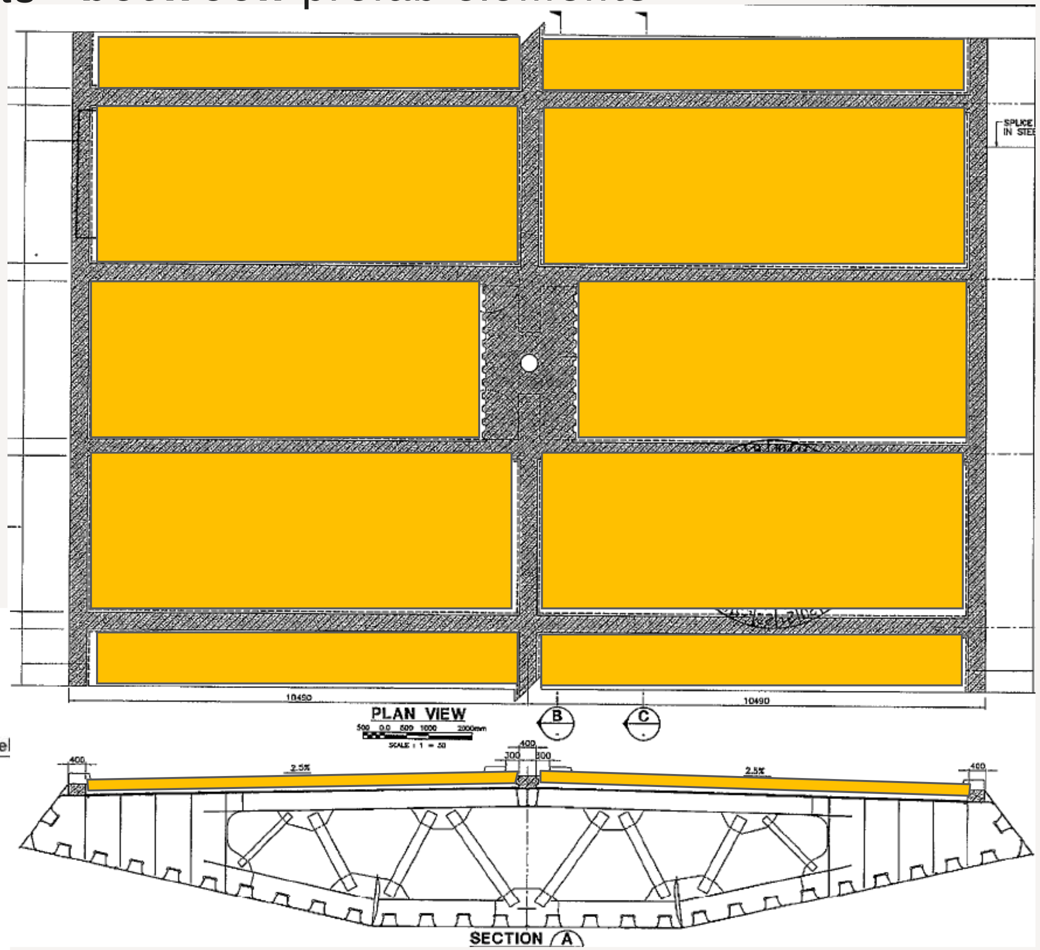
- Concrete slab typically not less than 250mm thick
- In situ concrete
  - Uniform concrete
  - Gives considerable work on site
- Prefabricated element
  - Less work on site – optimised fabrication
  - Less weather dependent
  - Less creep and shrinkage
  - Higher accuracy
  - Not practical shear connection between steel and concrete
- Prefabricated element + in situ concrete
  - Typically preferred method

Girder types – concrete prefabricated + in situ slab

Prefabricated filligran elements with in situ casting **on top** of prefab elements

Prefabricated elements with situ stitches **between** prefab elements





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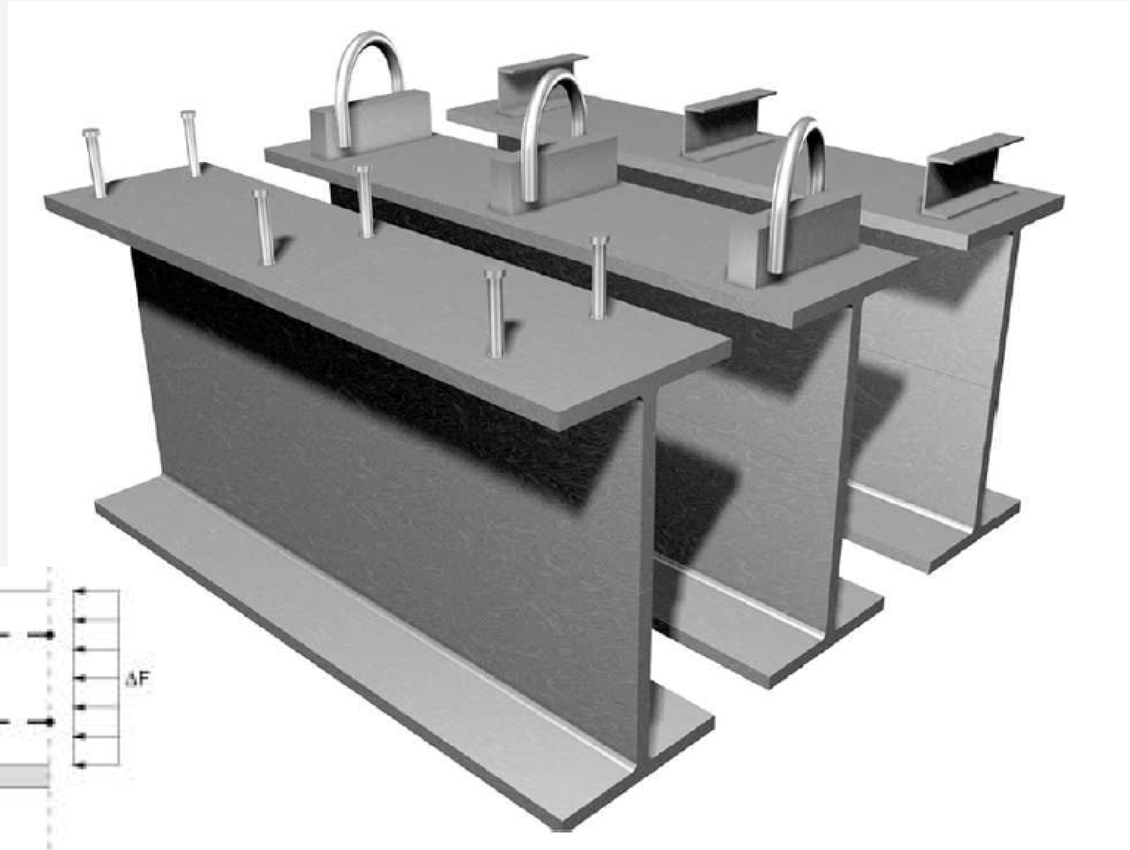
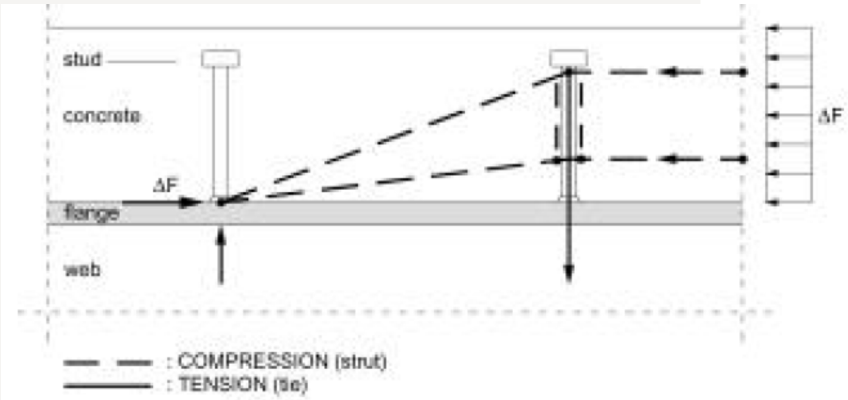
Shear connectors

- Types:
  - Headed studs
  - Bars with hoops
  - Channels





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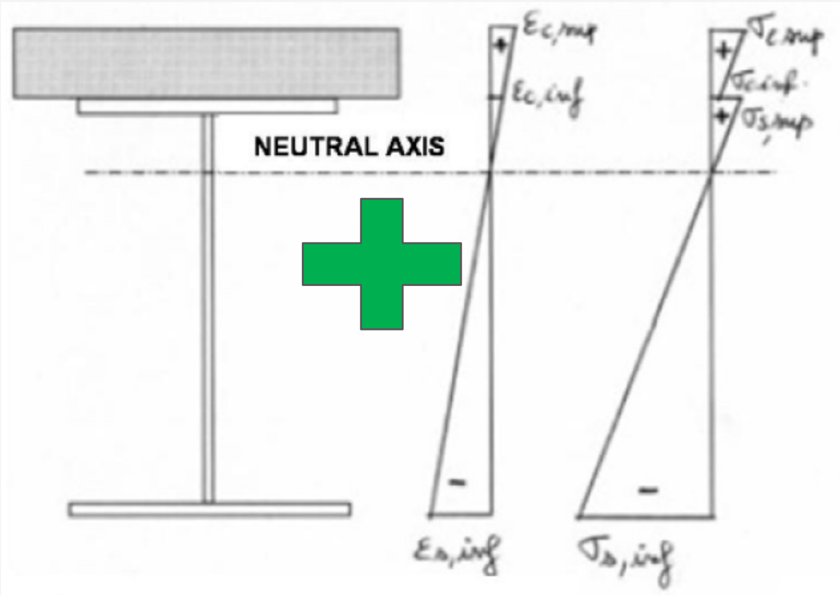
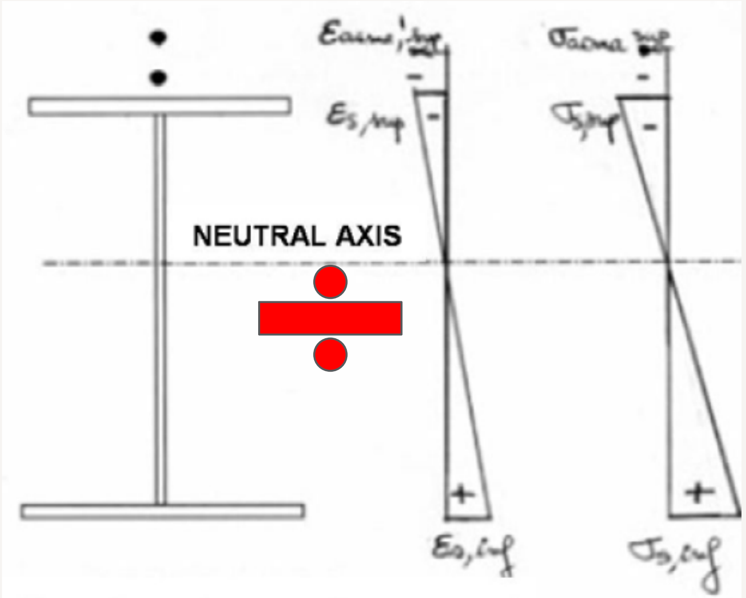
Design and structual calculations

› Stress and strains in composite section subjected to bending:



Positive bending moment



Negative bending moment

› Negative bending moment should be limited. This can be done by "intelligent" construction methods

Design and structural calculations

- "Accounting" of section forces and stresses is more difficult to handle than for all steel sections
- Different sets of section forces and cross sections must be considered and superimposed:
  - Dead loads of steel and part of concrete typically taken in steel alone before composite action is achieved
  - Composite action achieved gradually along the length of the bridge
- Time depending factors:
  - Due to creep forces tend to shed from concrete to steel for long term actions
  - Creep and shrinkage effects difficult to handle manually. Typically the FE-program includes creep and shrinkage which is modelled as part of the material properties. This requires relatively advanced calculation tools.
  - Typically structure considered at time of opening of bridge (t=0) (governing for concrete) after end of service life (100 years) (governing for steel)

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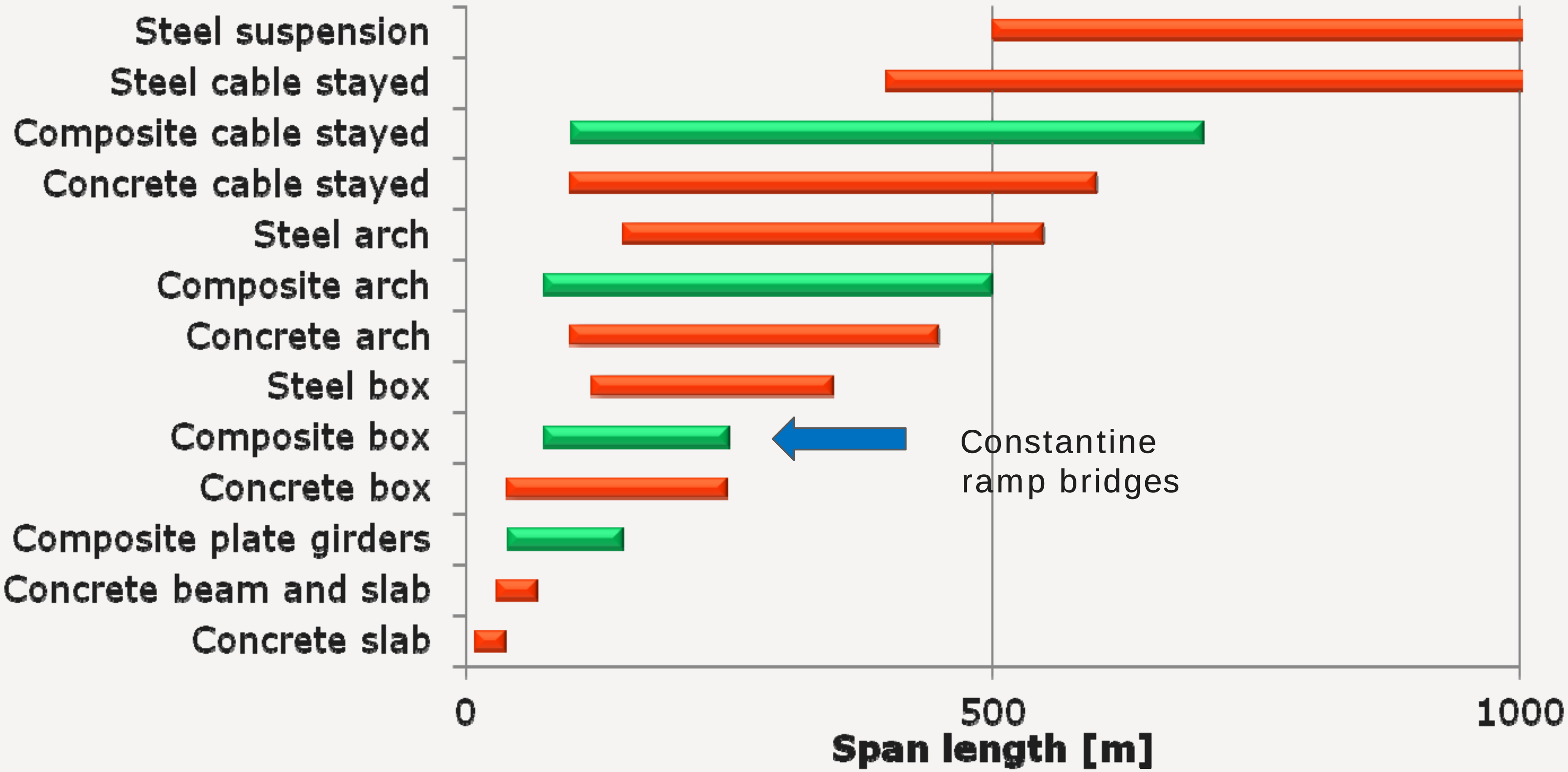
Bridge types for various span lengths



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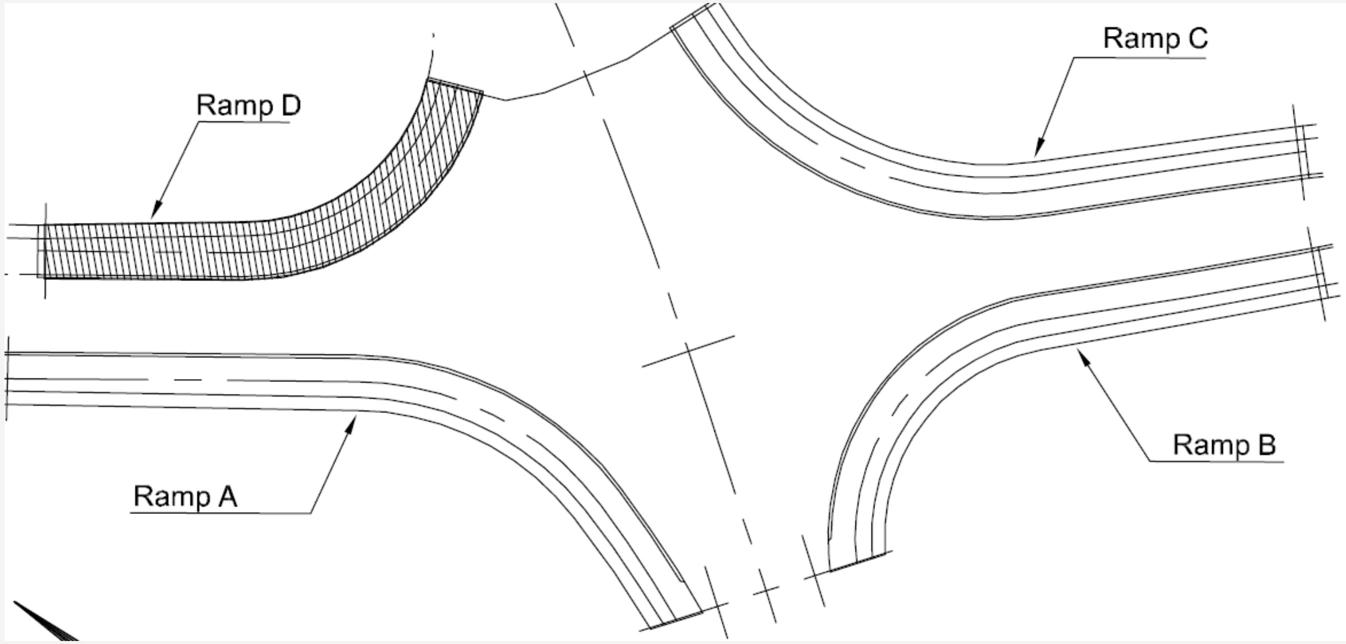
Constantine

› Four curved ramp bridges currently under construction



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Constantine – reason for choosing composite

- Difficult site conditions for access with steep slopes
- Contractor preference to avoid expensive scaffolding on steep slopes but rather lift self supporting steel structure.

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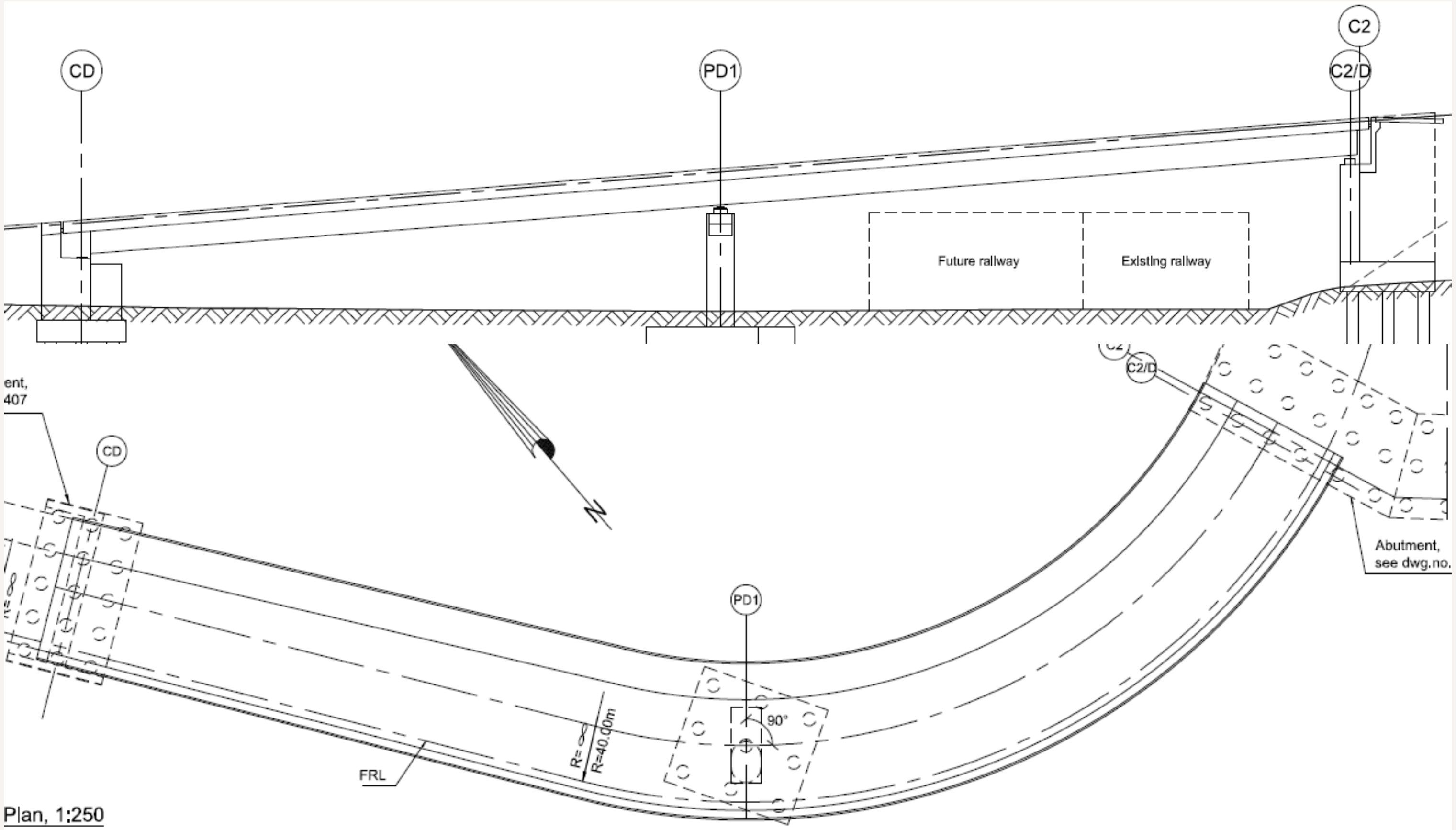
Constantine



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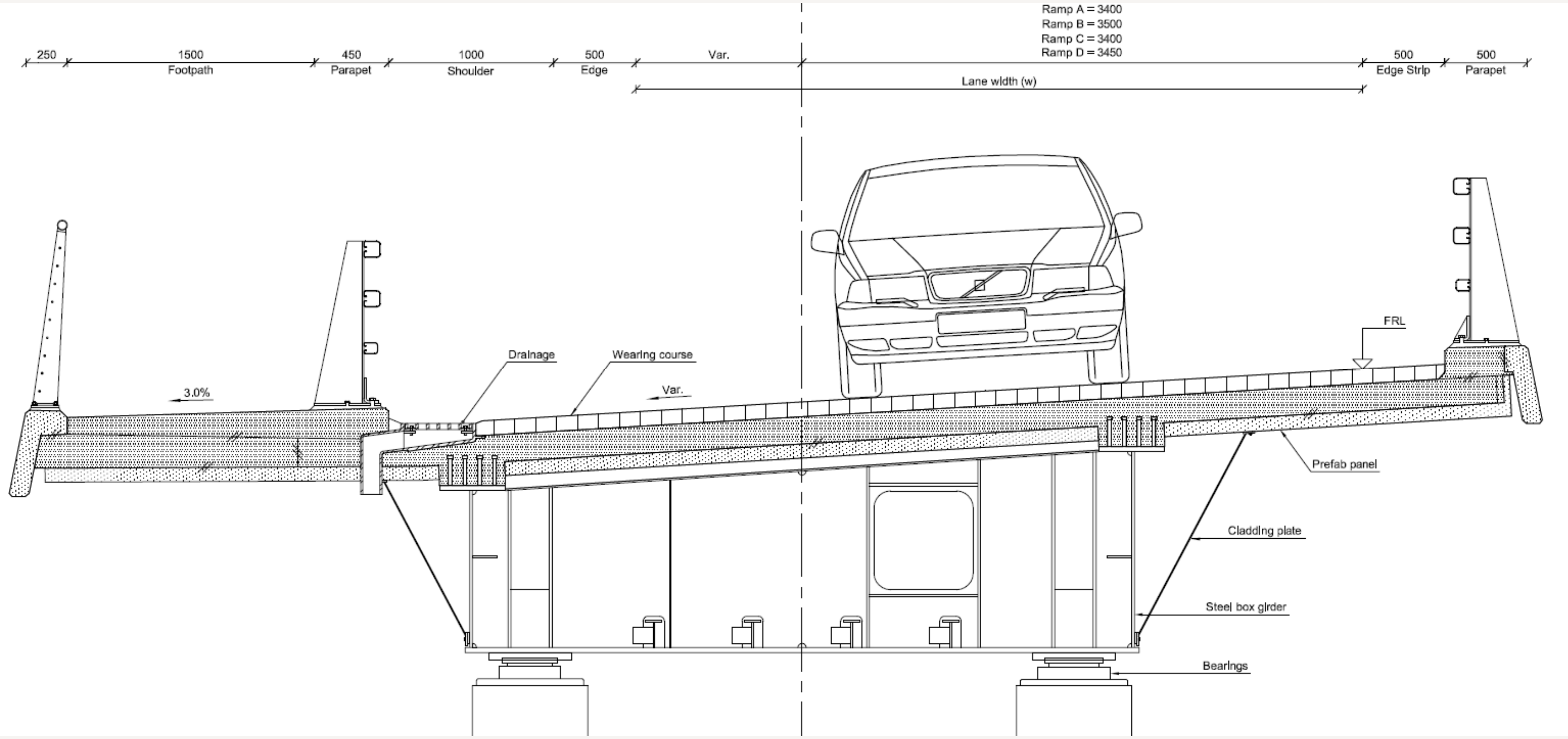
Constantine

› Steel box with 250mm concrete deck slab composed of filligran elements and in situ concrete on top



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Constantine – steelwork

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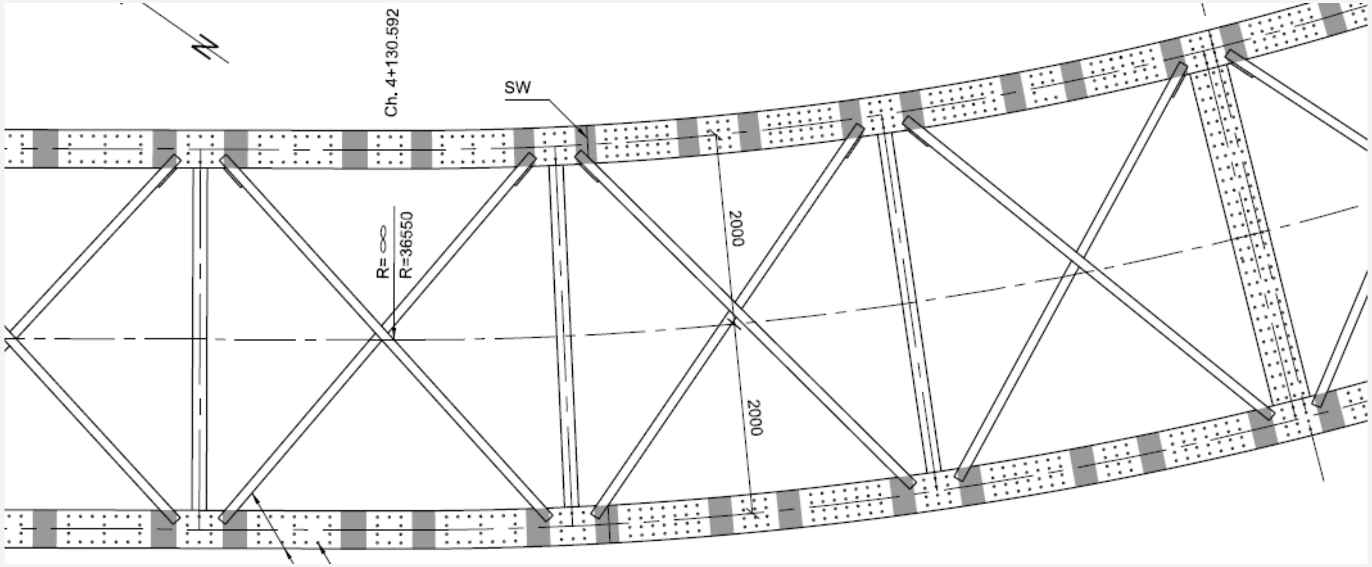
Constantine – steelwork

› Bracing



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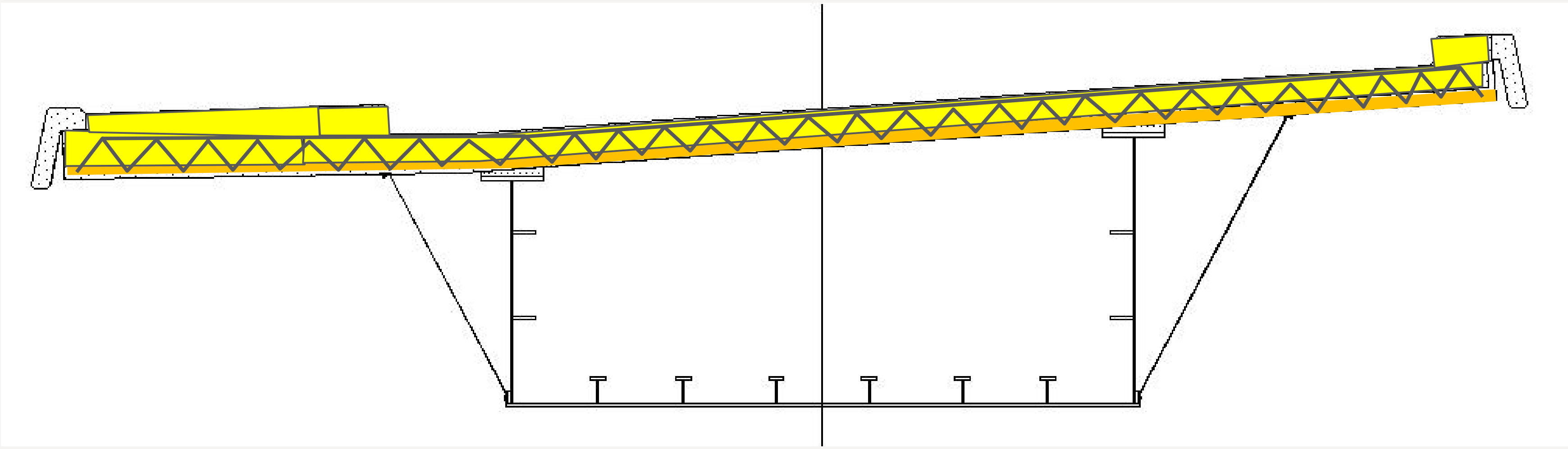
Constantine – Concrete slab

- Prefabricated filligran elements with cast in reinforcement truss (85mm)
- Prefabricated edge beams
- In situ concrete cast in several stages (165mm)



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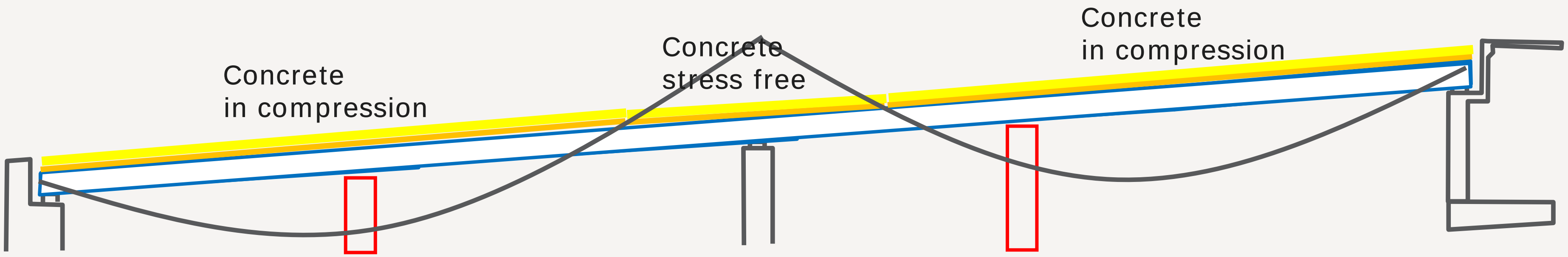
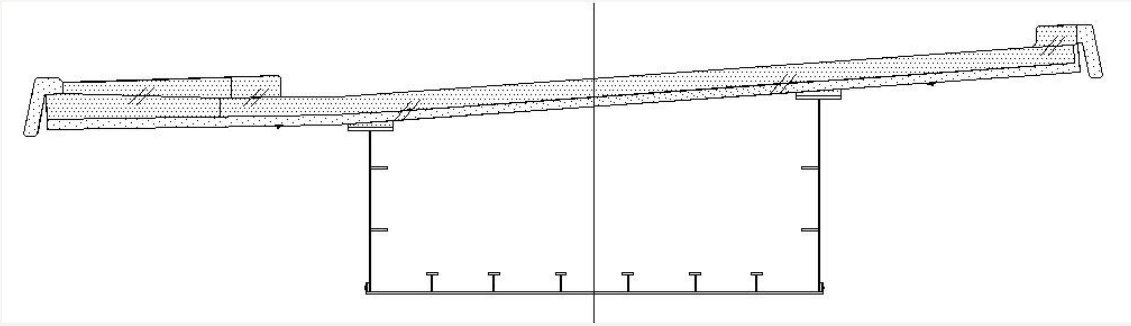
Constantine – erection sequence



- Substructure
- Temporary supports
- Steel girder
- Steel connected
- Prefab + concrete sides
- Remove temporary supports
- Prefab + concrete mid



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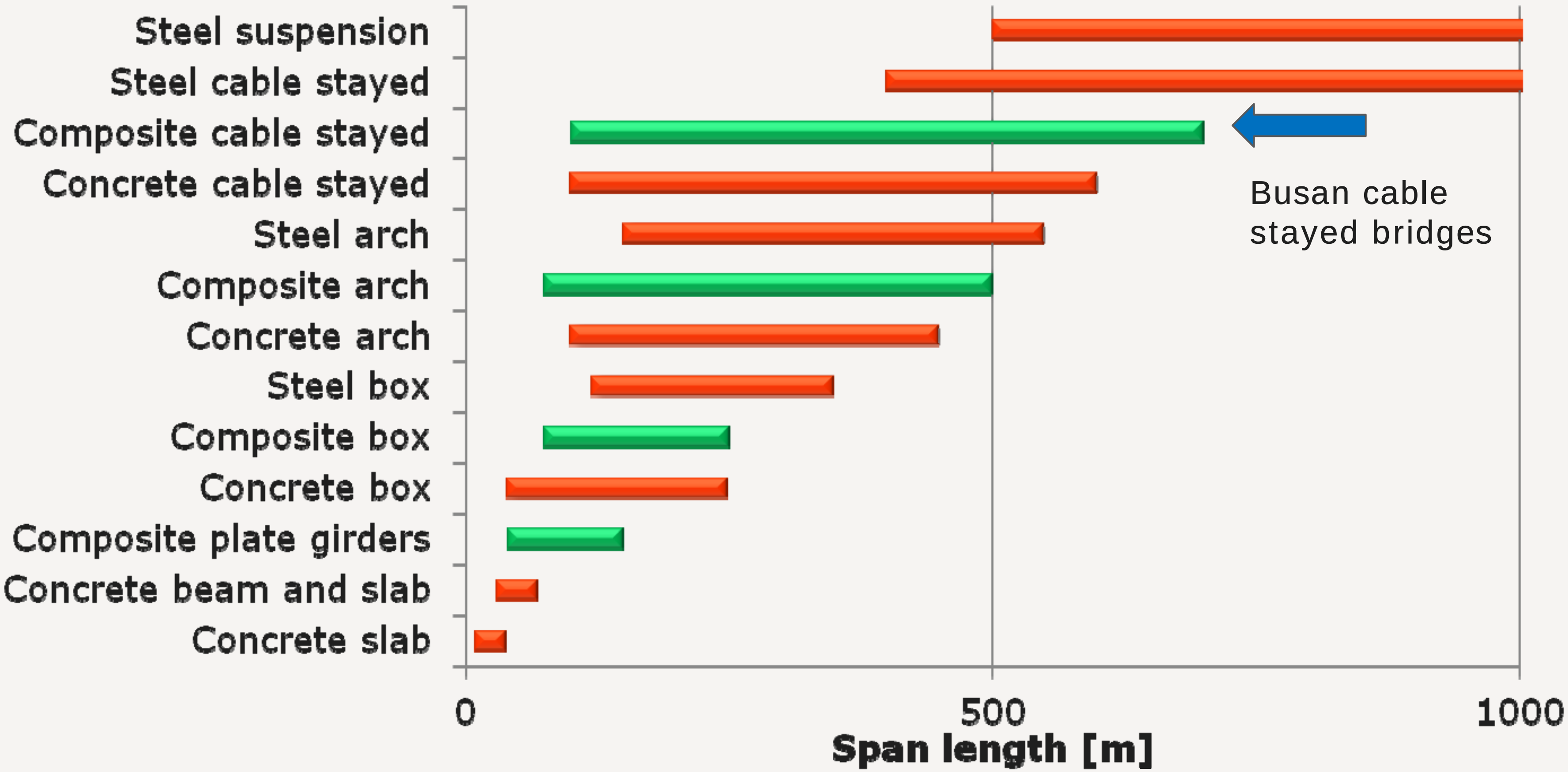
Bridge types for various span lengths



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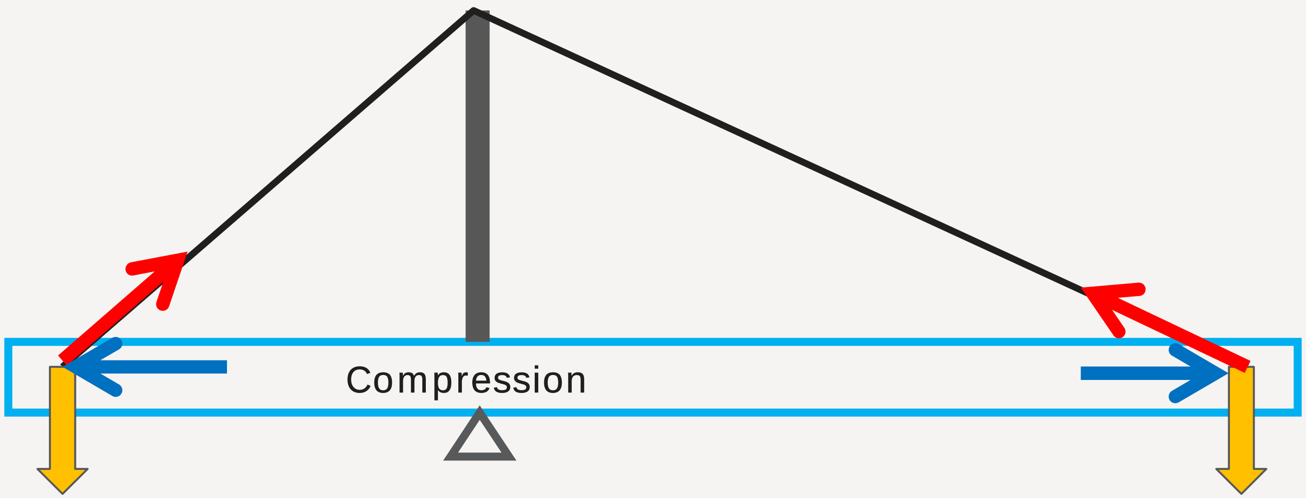
Composite cable stayed bridges



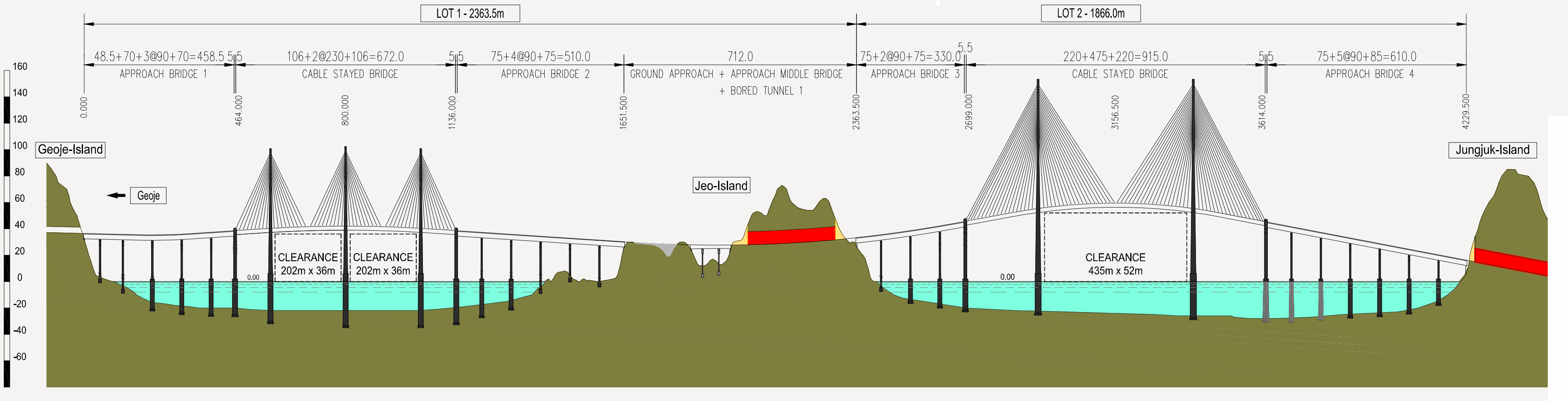
Concrete

Concrete/Composite

Composite/Steel

Steel

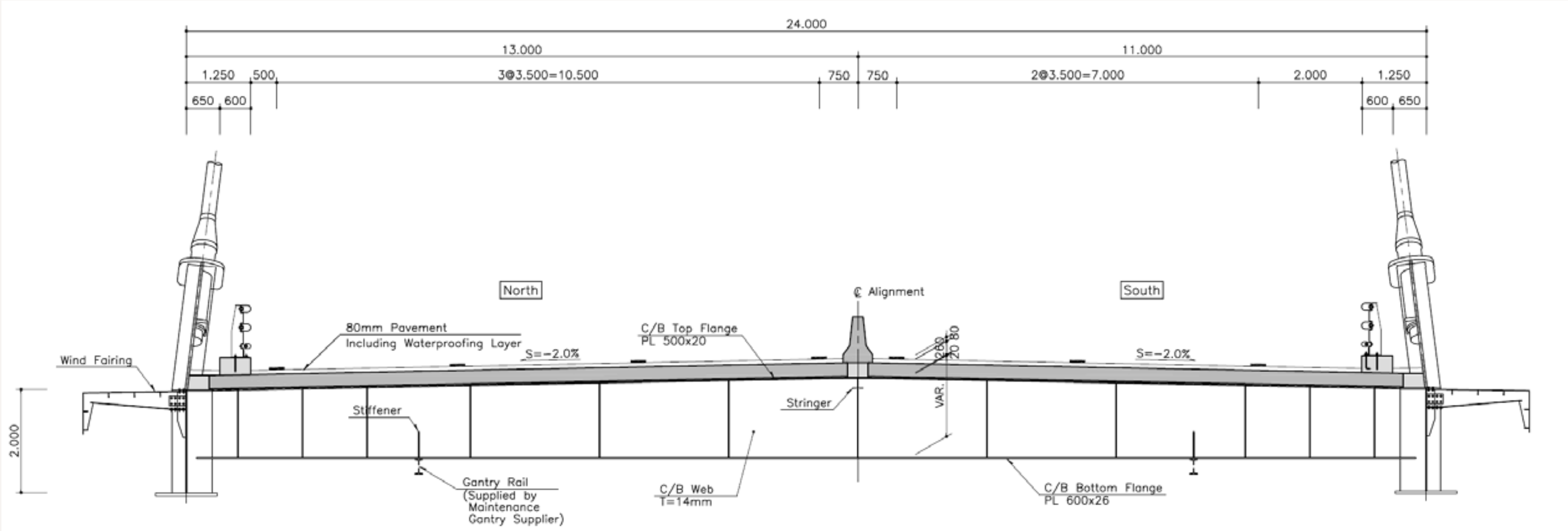
Busan



LOT 1 - 2363.5m
LOT 2 - 1866.0m
48.5+70+3@90+70=458.5
APPROACH BRIDGE 1
5.5
106+2@230+106=672.0
CABLE STAYED BRIDGE
5.5
75+4@90+75=510.0
APPROACH BRIDGE 2
712.0
GROUND APPROACH + APPROACH MIDDLE BRIDGE + BORED TUNNEL 1
75+2@90+75=330.0
APPROACH BRIDGE 3
5.5
220+475+220=915.0
CABLE STAYED BRIDGE
5.5
75+5@90+85=610.0
APPROACH BRIDGE 4
0.000
464.000
800.000
1136.000
1651.500
2363.500
2699.000
3156.500
3614.000
4229.500
160
140
120
100
80
60
40
20
0
-20
-40
-60
Geoje-Island
Geoje
Jeo-Island
Jungjuk-Island
CLEARANCE
202m x 36m
CLEARANCE
202m x 36m
CLEARANCE
435m x 52m
0.00
0.00

COWI

Busan



2009 main span 1018m

Busan

Busan

When to use composite bridges

- When steel and concrete can be utilised the way they work best
- Reasons for choosing composite over steel bridges:
  - Less expensive than orthotropic steel decks
  - Concrete requires less maintenance than steel
- Reasons for choosing composite over concrete bridges:
  - Gives smaller demands on substructures and stay cables
  - Requires less temporary structures for execution
  - By using prefabricated elements it is possible to speed up construction and achieve high manufacturing accuracy

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