Multiconsult

Mulighetsstudie Sulafjorden

Per Horn, Basile Bonnemaire og Birger Opgård,
Molde 17.desember 2015

Multiconsults forhold til fjordkryssinger

1. Forstå hva et samferdselsanlegg er fra et vei- og brustånsted
2. Erfaring med marine konstruksjoner er sentralt, i tillegg til store bruspenn
   a) Forstå miljølastene og deres påvirkning på konstruksjonene
   b) Analyseverktøy skal velges og brukes/ tilpasses
   c) Forstå bygging, transport, installasjon, operasjon

Samarbeidsgruppen

- E.D.IN med professor Fabio Brancaleoni: spesialist store bruspenn
- Kværner: spesialister på å bygge/ installere offshore betongkonstruksjoner
- Aker Solutions: utvikling og prosjektering av flytende offshore-konstruksjoner
- Marintek: Erfaring global respons av marinstrukturer (inkl. programvare)
- Semar: analyse og utførelse av marine operasjoner
- Selberg arkitekter

Deltagere i møtet

- Basile Bonnemaire, avdelingsleder Marin Teknologi. Presenterer Metocean rapporten
- Birger Opgård, oppdragsleder. Presenterer mulighetsstudiet
- Roar Lie, konstruksjonsspesialist, ansvarlig for rørbrua
- Per Horn, avdelingsleder Olje & gass

Mulighetsstudie kryssing av Sulafjorden

Metocean design basis

Kreativ fase → Silings fase → Detaljerings fase

Metocean design basis

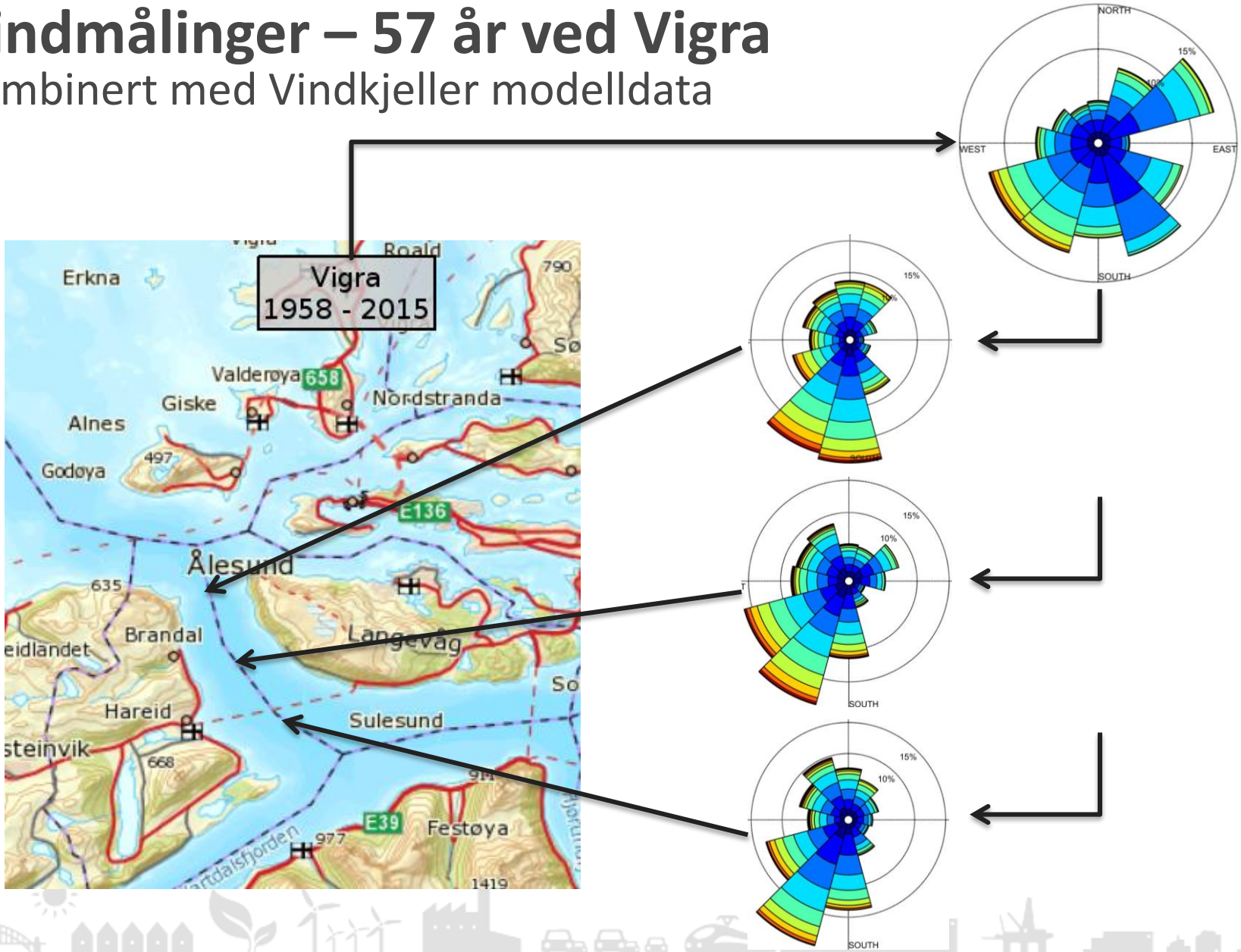
Metocean design basis - utfordringer

- Stort område – stor geografisk variasjon i det fysisk miljø (e.g. vind eller bølger) over området
- Ikke helt offshore og ikke helt onshore
- Lite datagrunnlag

- Fremgangsmåte:
  - Analyse av eksisterende data
  - Simulering av vind, vindbølger, havdønning
  - Ekstrem analyse gir kartlegging av forventet ekstremene → Design grunnlag

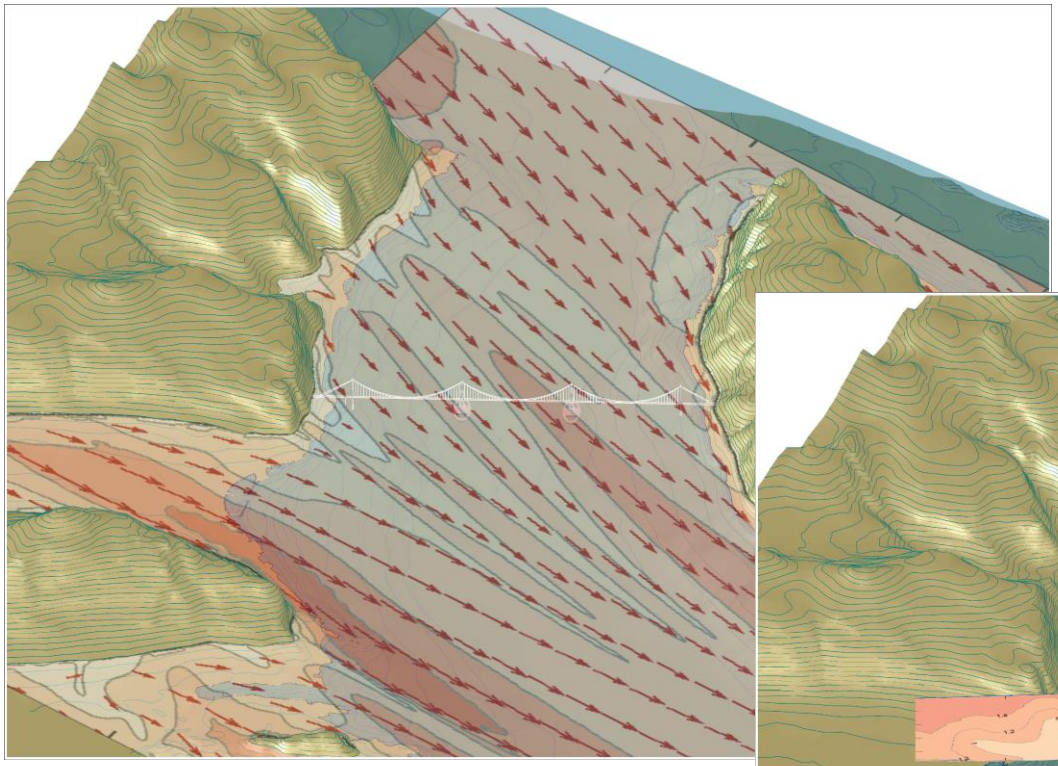
Vindmålinger – 57 år ved Vigra

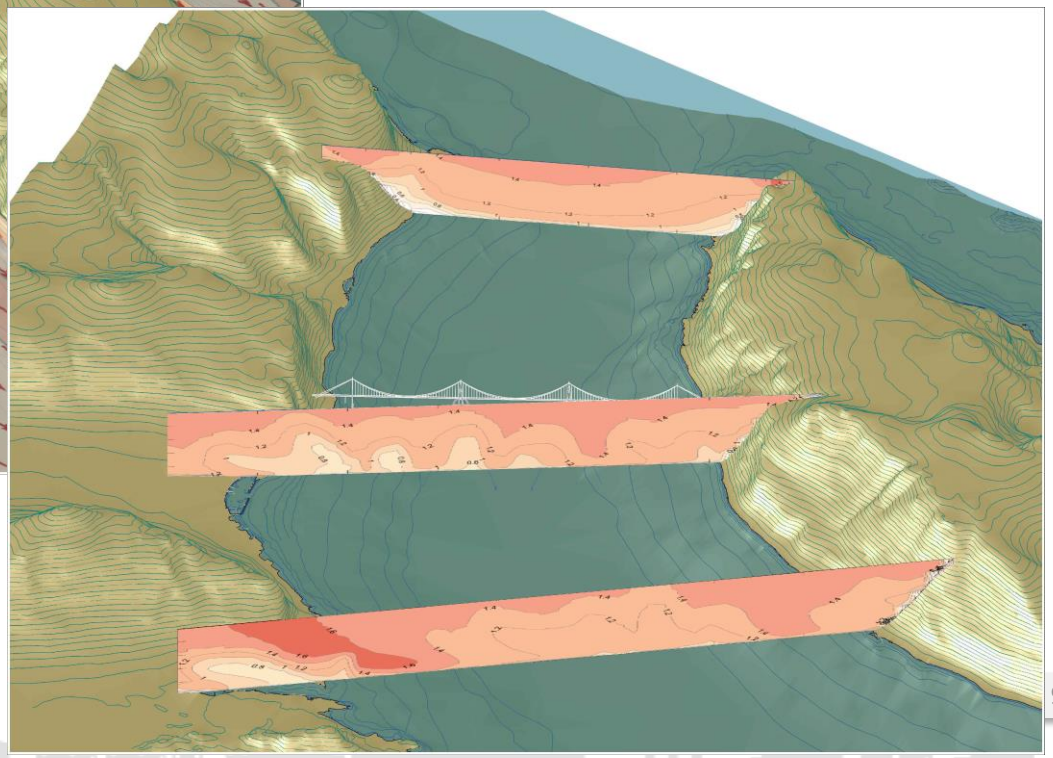
Kombinert med Vindkjeller modelldata



Vind simuleringer

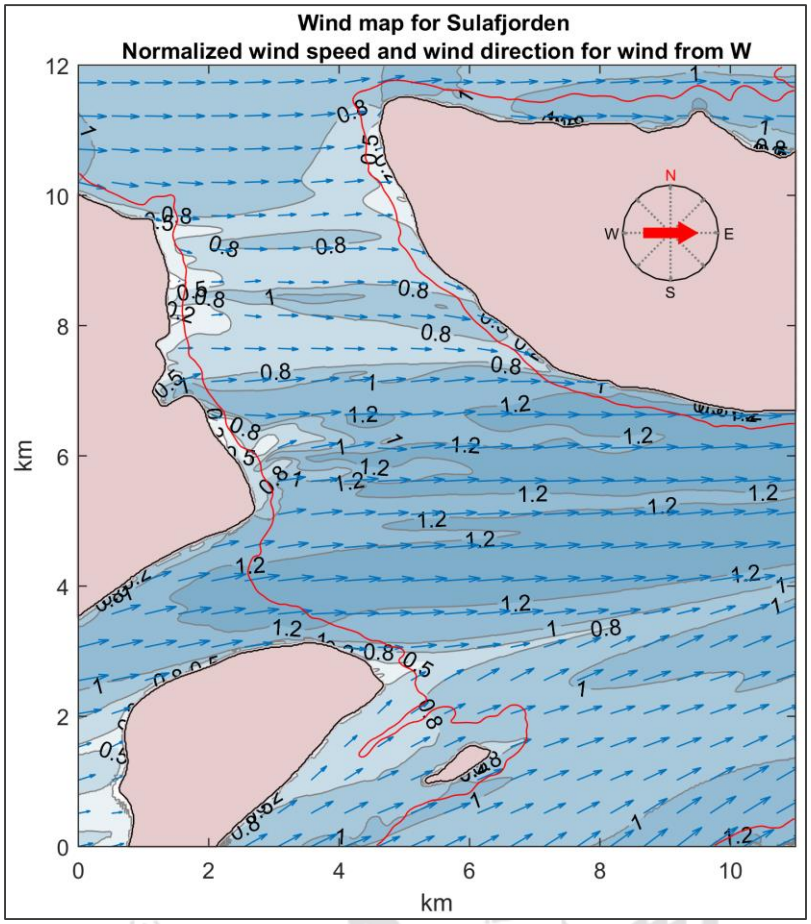
- 3D kartlegging av vindfelt og tilhørende turbulens intensitet

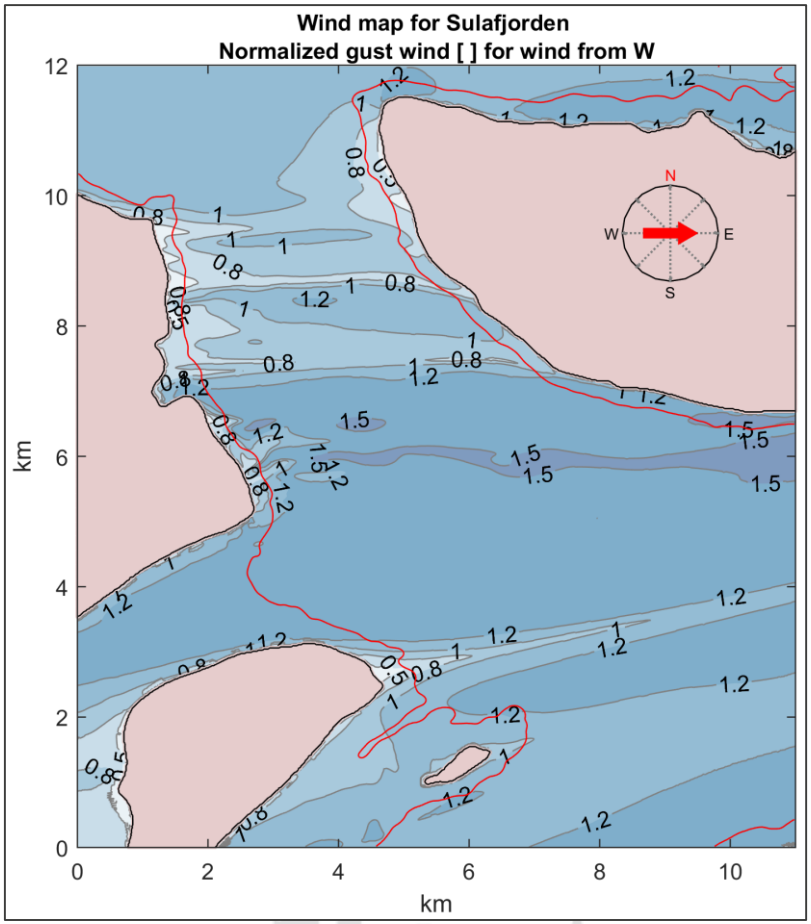




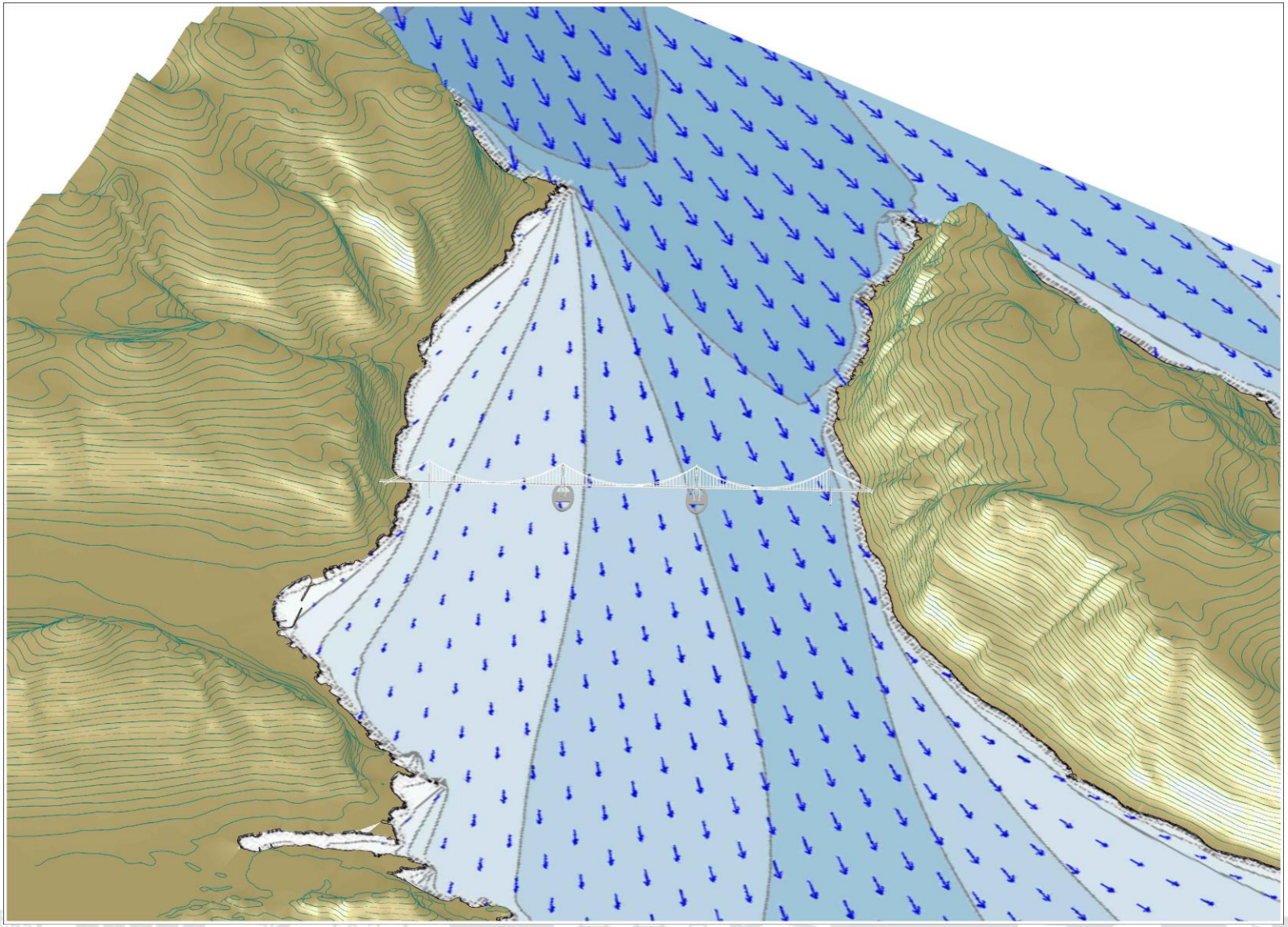
Vindfelt simuleringer over fjorden

- Eksempel: vindkart på 80 m høyde (middelvind og vindkast faktor)



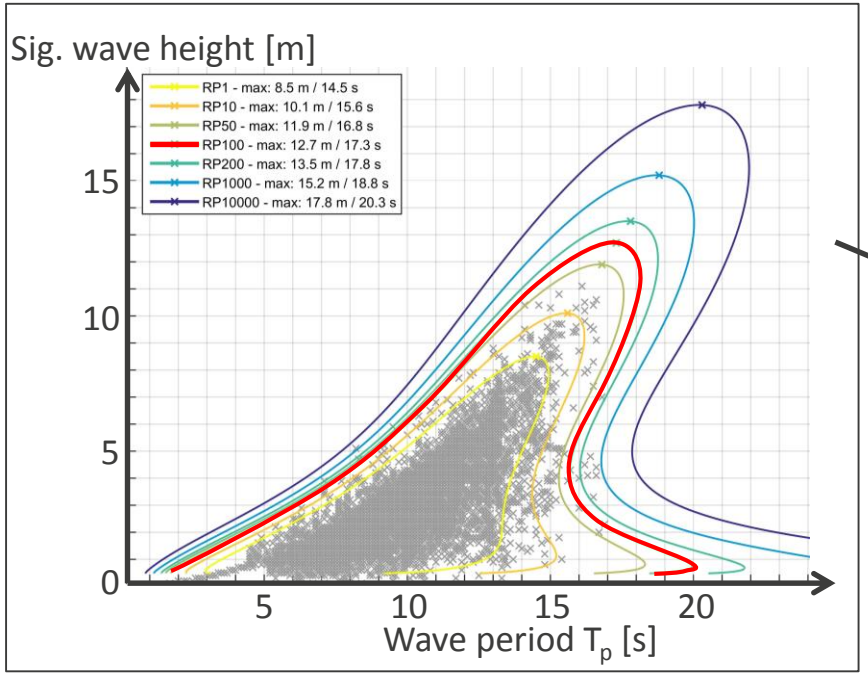


Bølge simuleringer



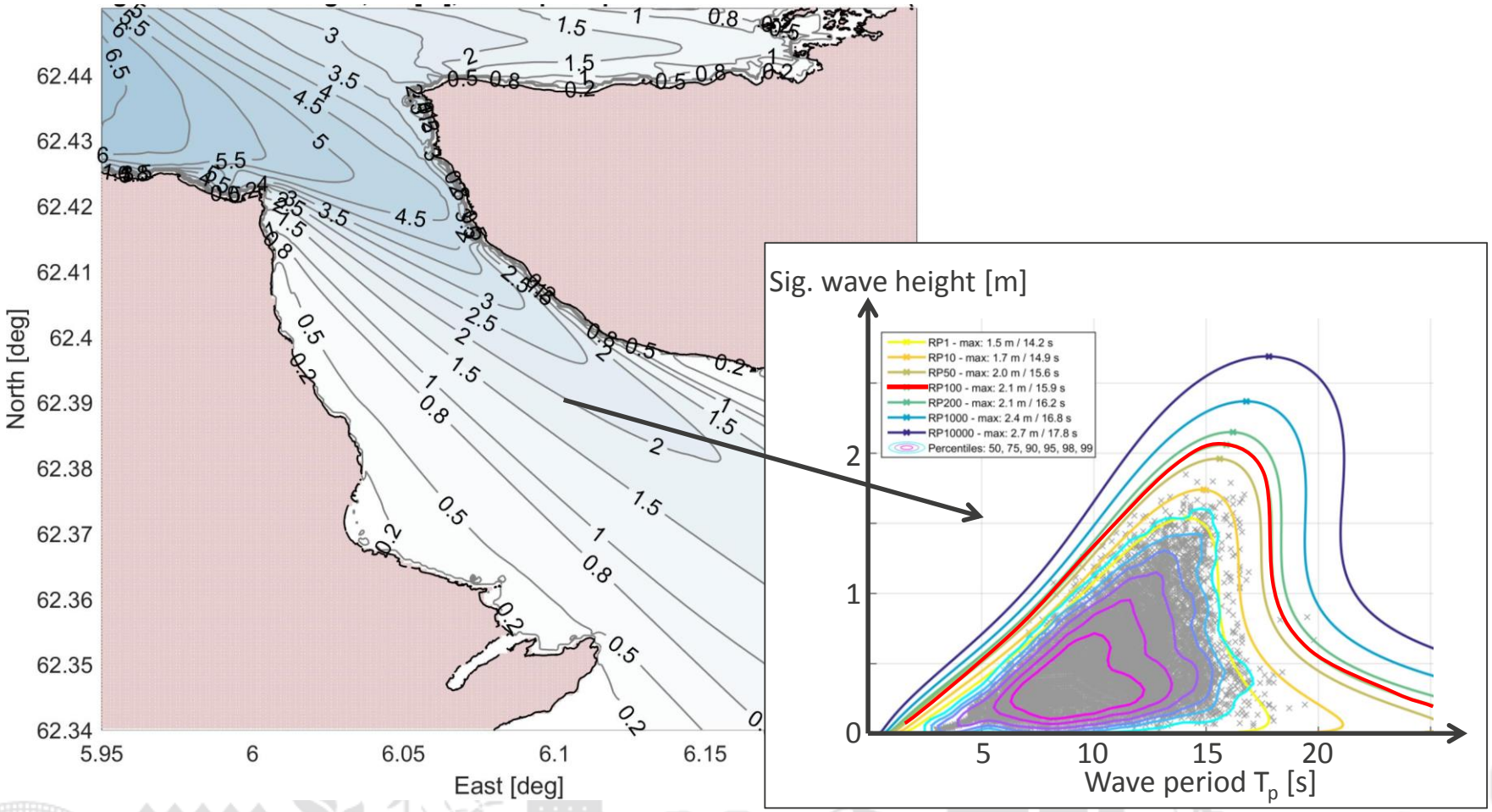
Havdønning forplantning – Offshore input

- Offshore bølge input



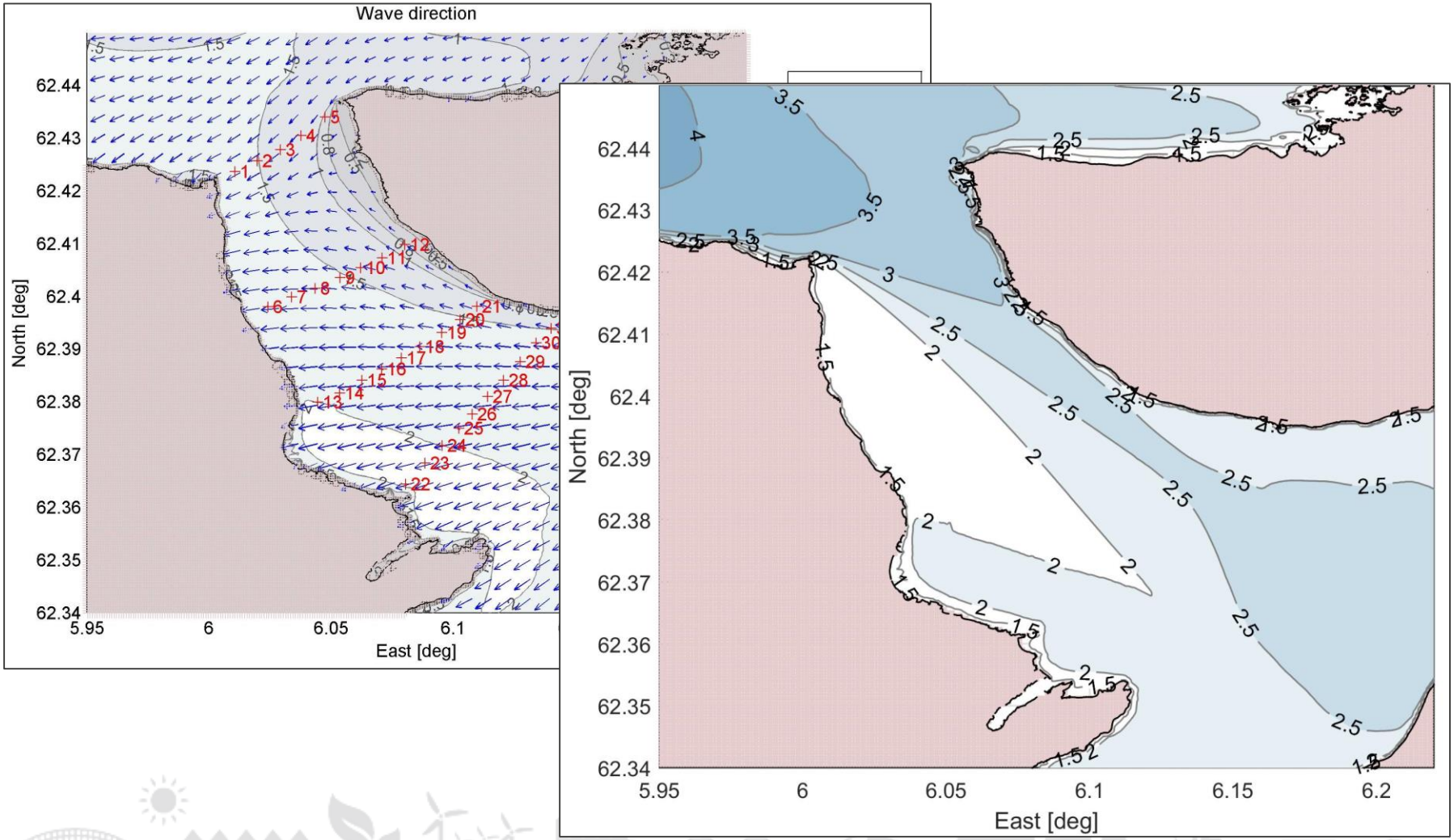
Havdønning i Sulafjord

- På lokalitet: Bølgehøyde kart, bølge retningsspektre, Hs-Tp kurver



Vindbølger i Sulafjord

- Bølgehøyde kart, bølge retningsspektre

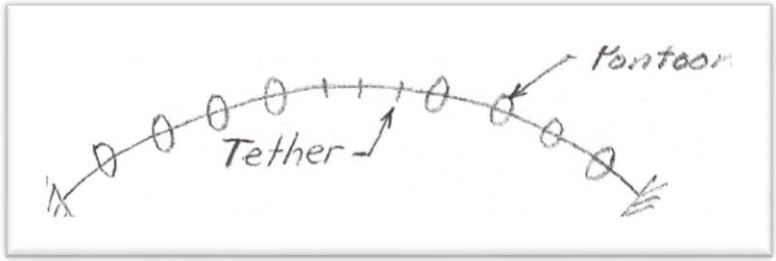


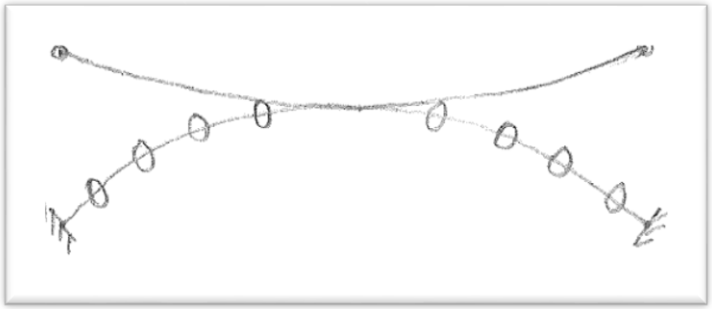
Metocean design grunnlag - Sulafjord

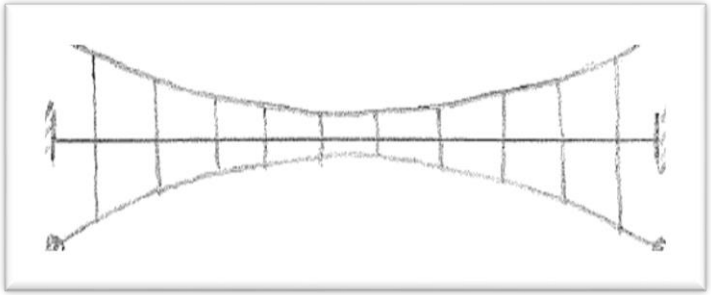
Parameter – 100 år returperiode		
Bølger	Havdønning	Hs: 2 - 5 m Tp: 10 - 17 s
	Vindbølger	Hs: 2 - 3.5 m Tp: 6 - 8 s
Vind	10 min vind, 70 m høyde	Vm: 40 - 43 m/s
Strøm	(antatt)	Vc: 1 m/s
Skredbølge	(Åknes)	Hmax: 1 m Tp: 60 s

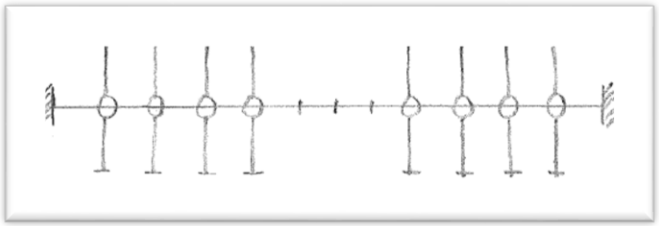
Kreativ og silingsfase

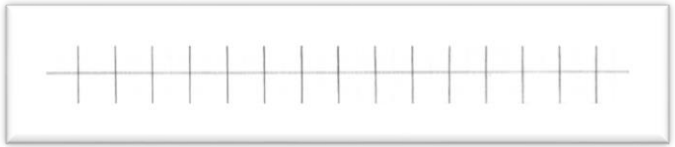
Kreativ fase -rørbruer



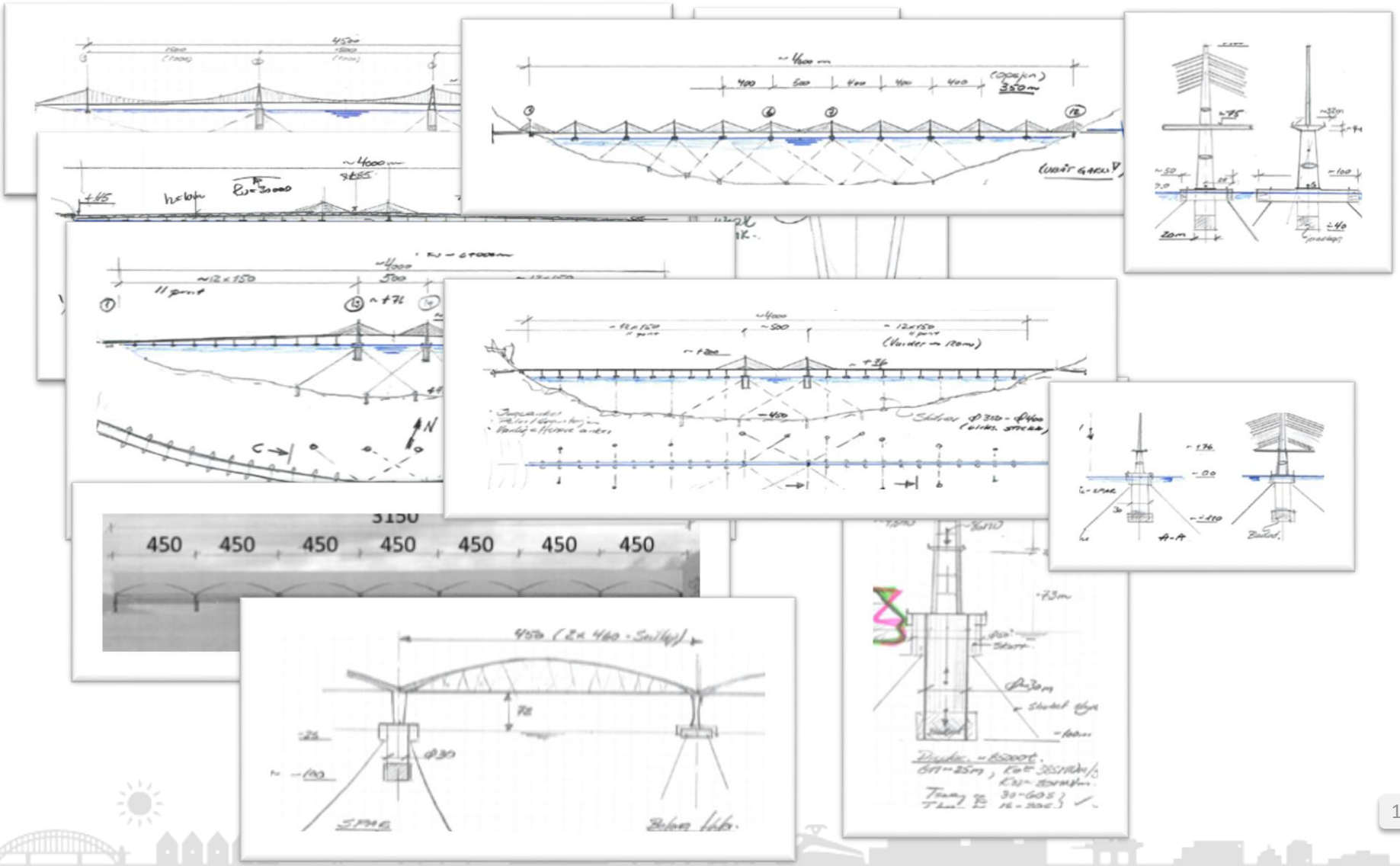




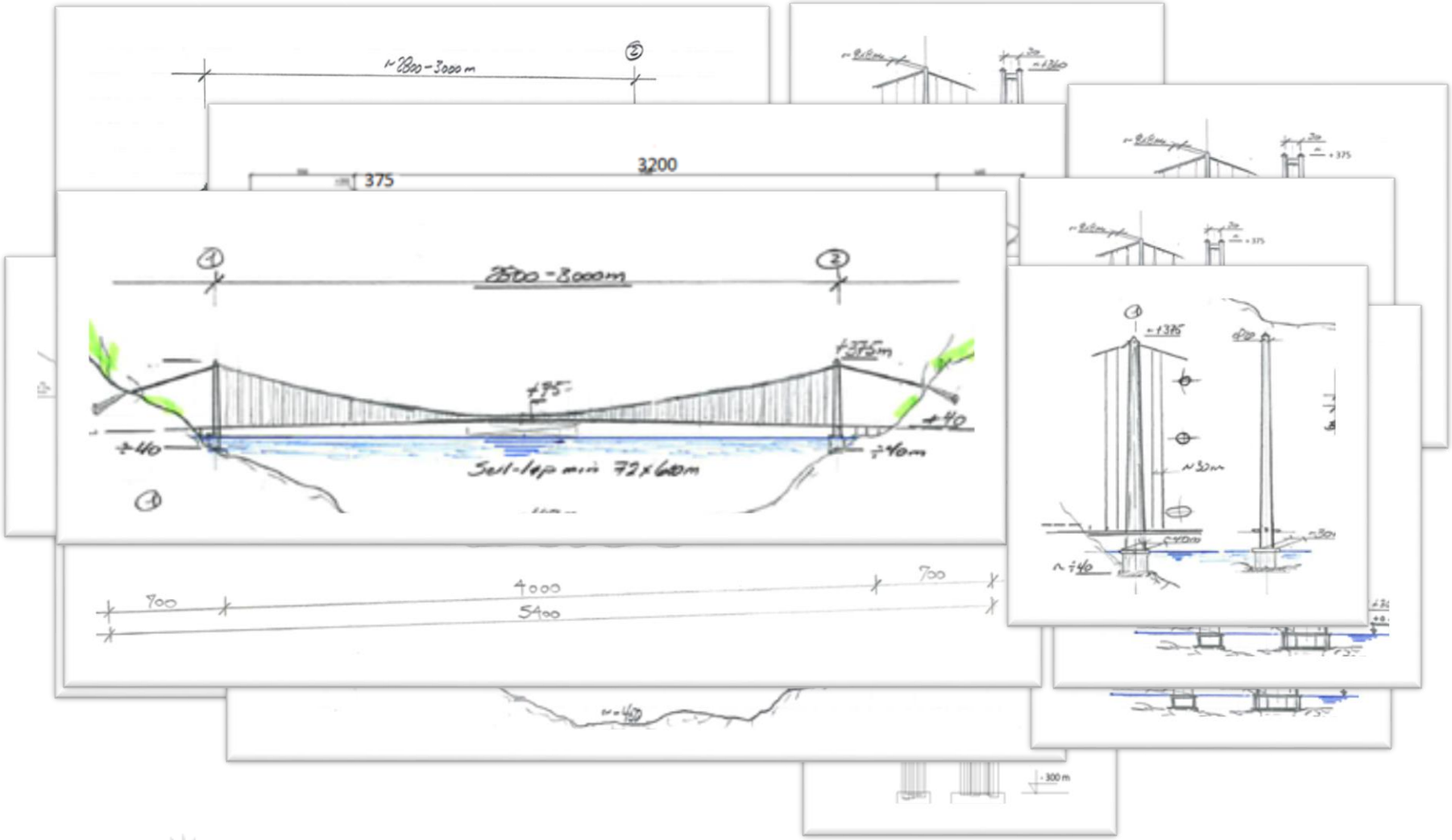




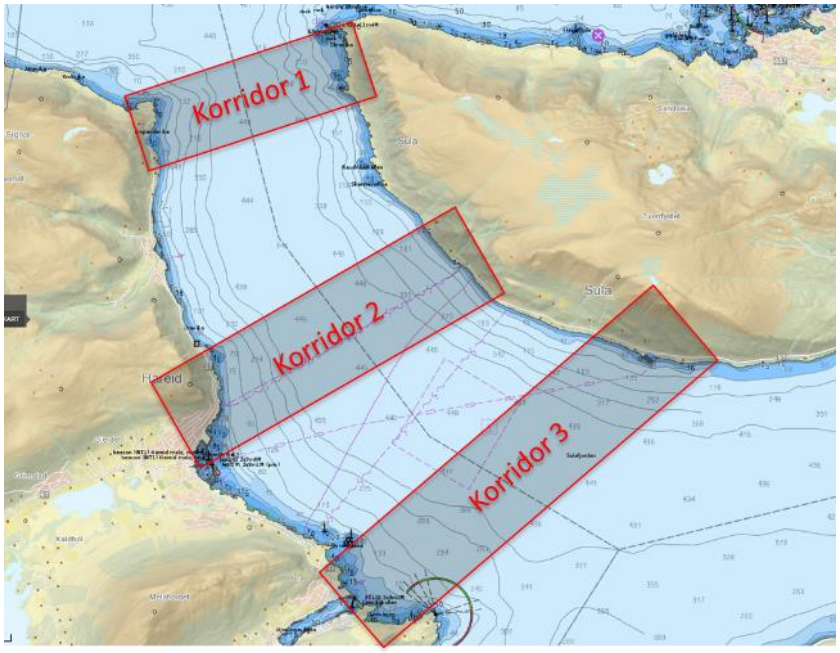
Kreativ fase - flytebruer



Kreativ fase - hengebruer

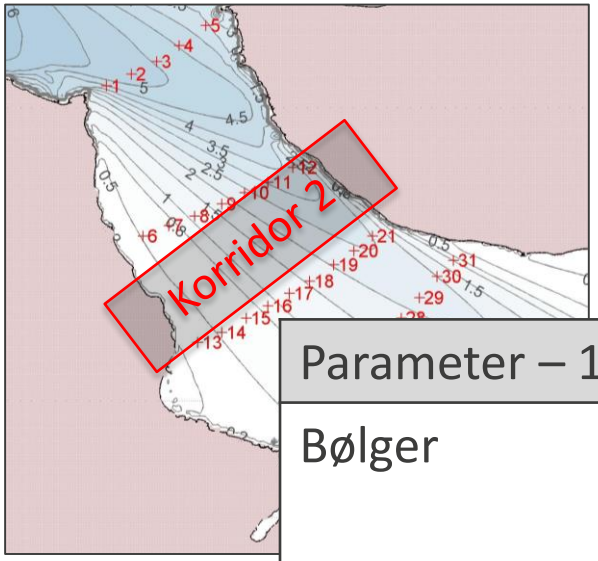


Silingsfase



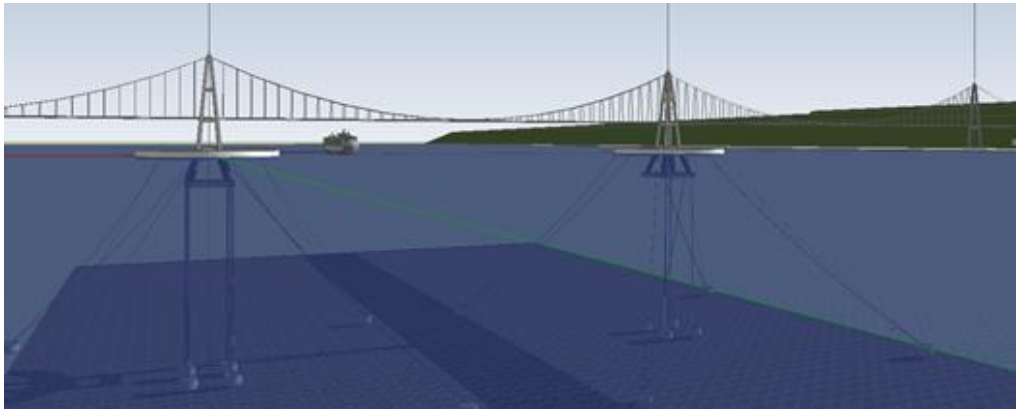
- Hengebru med et langt hovedspenn (2800 m) i korridor 1
- Rørbru i kurve med kombinasjon av pontonger og stag i korridor 2
- Flytende hengebru med tre spenn på to flytere i korridor 2

Miljølaster – Korridor 2



Parameter – 100 år returperiode		
Bølger	Havdønning	Hs: opp til 2.5 m Tp: 13-17 s
	Vindbølger	Hs: opp til 2.5 m Tp: 6 - 8 s
Vind	10 min vind, 70 m høyde	Vm: 38 – 42 m/s
Strøm	(antatt)	Vc: 1 m/s
Skredbølge	(Åknes)	Hmax: 1 m Tp: 60 s

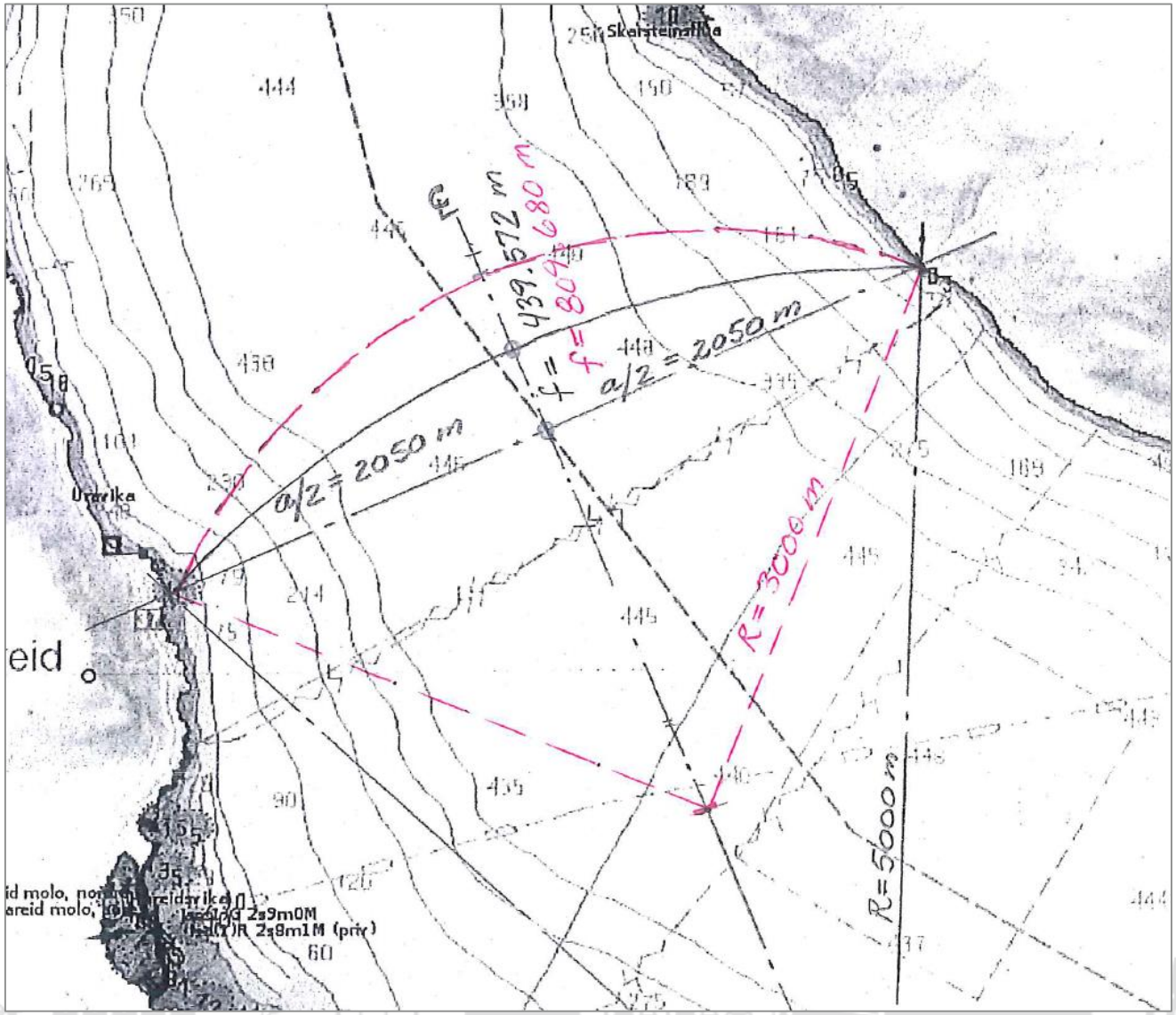
Skipsstøt



	Sognefjord	Sulafjord Mulighets-studie
Impact energy	1 563 MNm	2 000 MNm
Vessel displacement	31 500 t	40 000 t
Vessel velocity	17.7 knots	18 knots

Rørbru

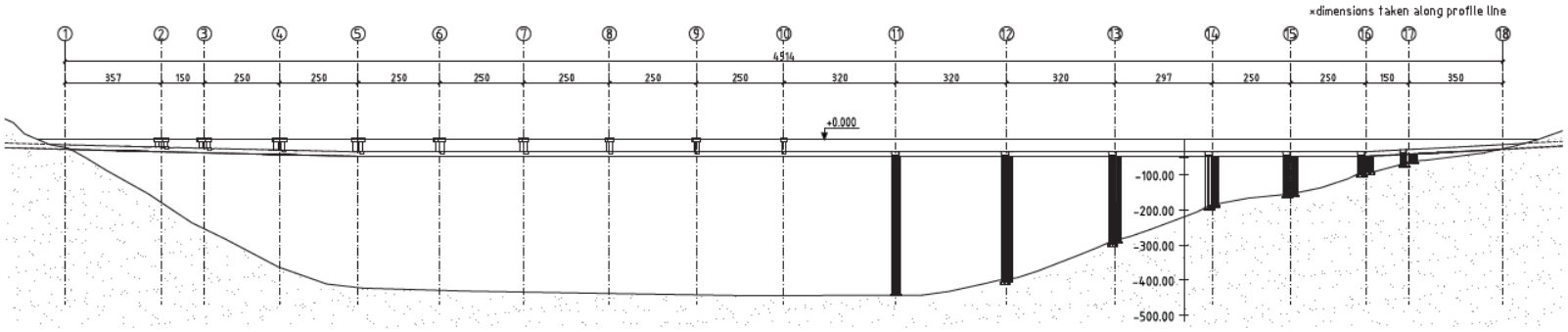
Rørbru


Skeinsteinaflka
Urarika
eid
a/2 = 2050 m
a/2 = 2050 m
f = 8079,680 m
439,572 m
R = 3000 m
R = 5000 m

Utfordringer

- Miljølaster (havbølger og vindbølger)
- Landfester
- Tunnel
- Robusthet
- Forankring
- Skipsstøt på pontonger
- Bygging, transport, installasjon

Geometri



Elevation
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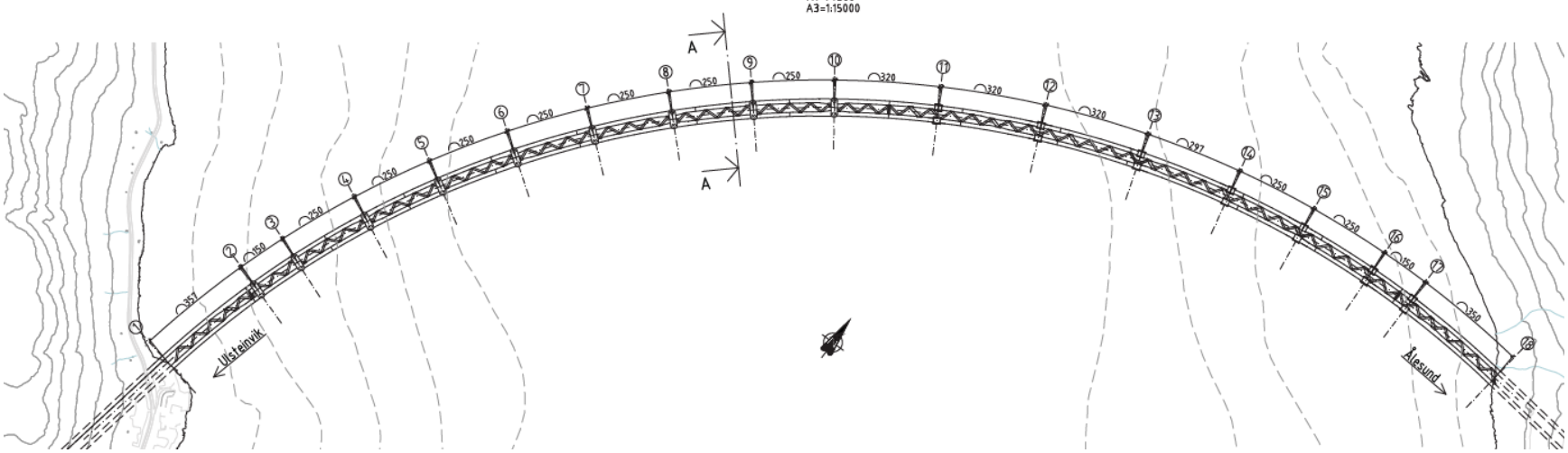
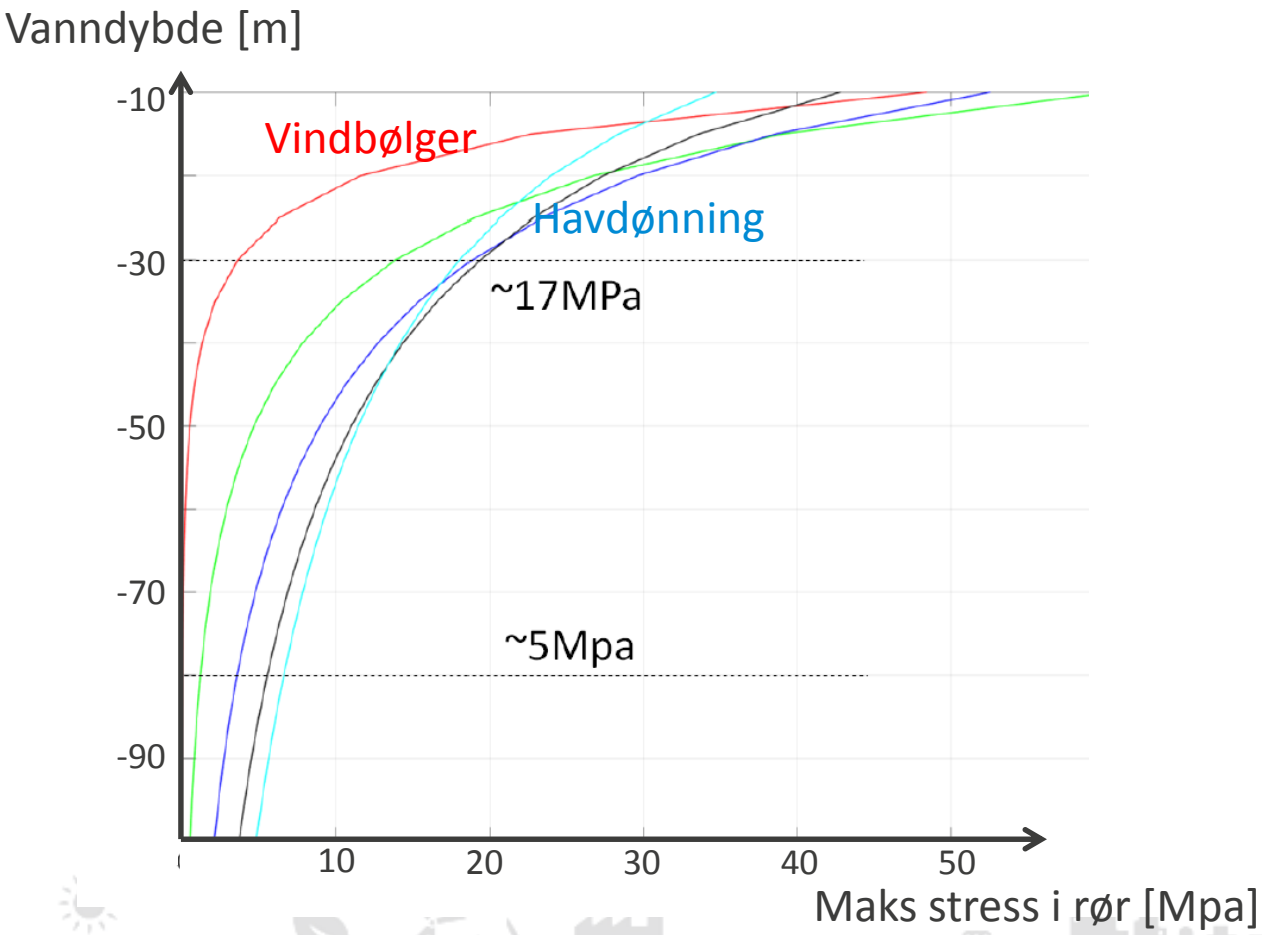
A3=1:15000



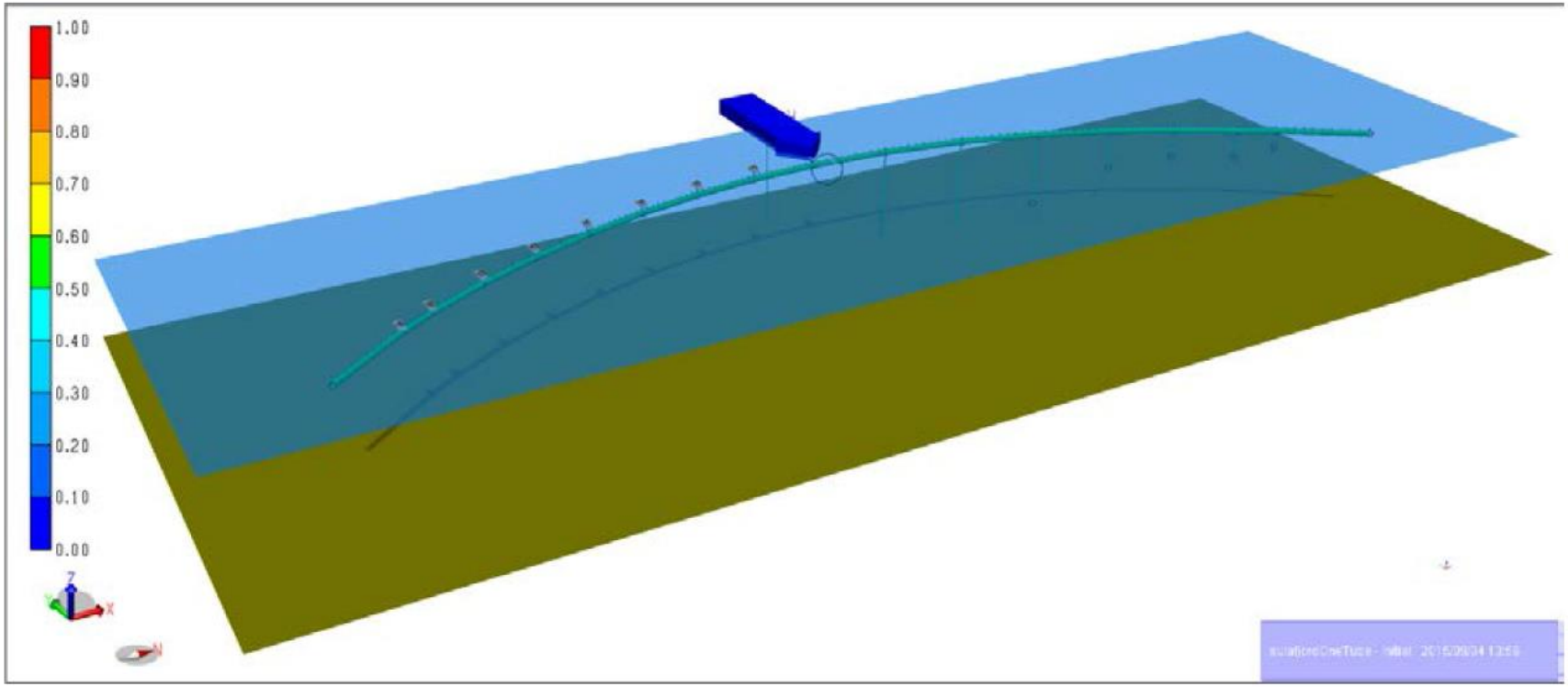
Dybde optimalisering

- Større bølgelaster ved vannoverflate

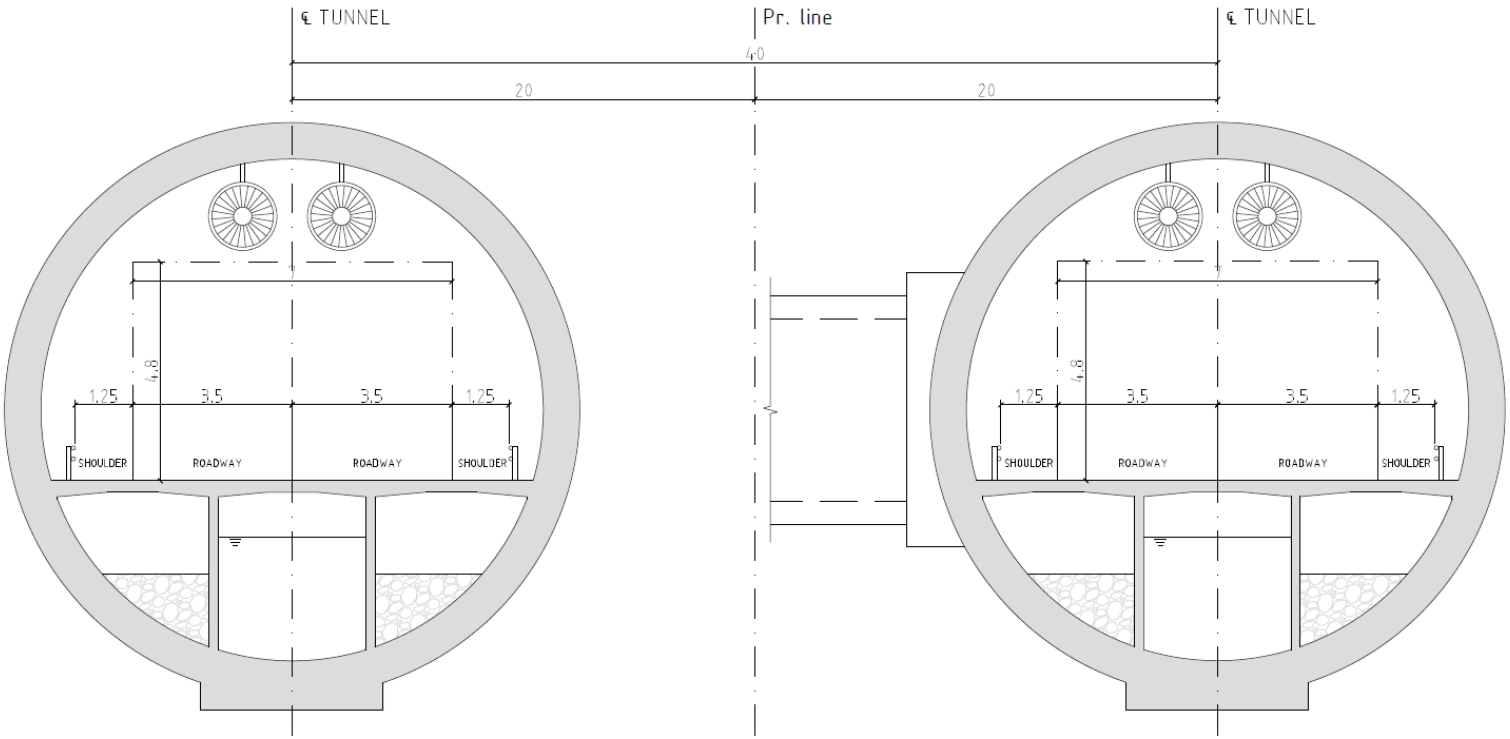


Global dynamisk analyse

- Globalrespons – hydrodynamiske laster (Simo&Riflex)

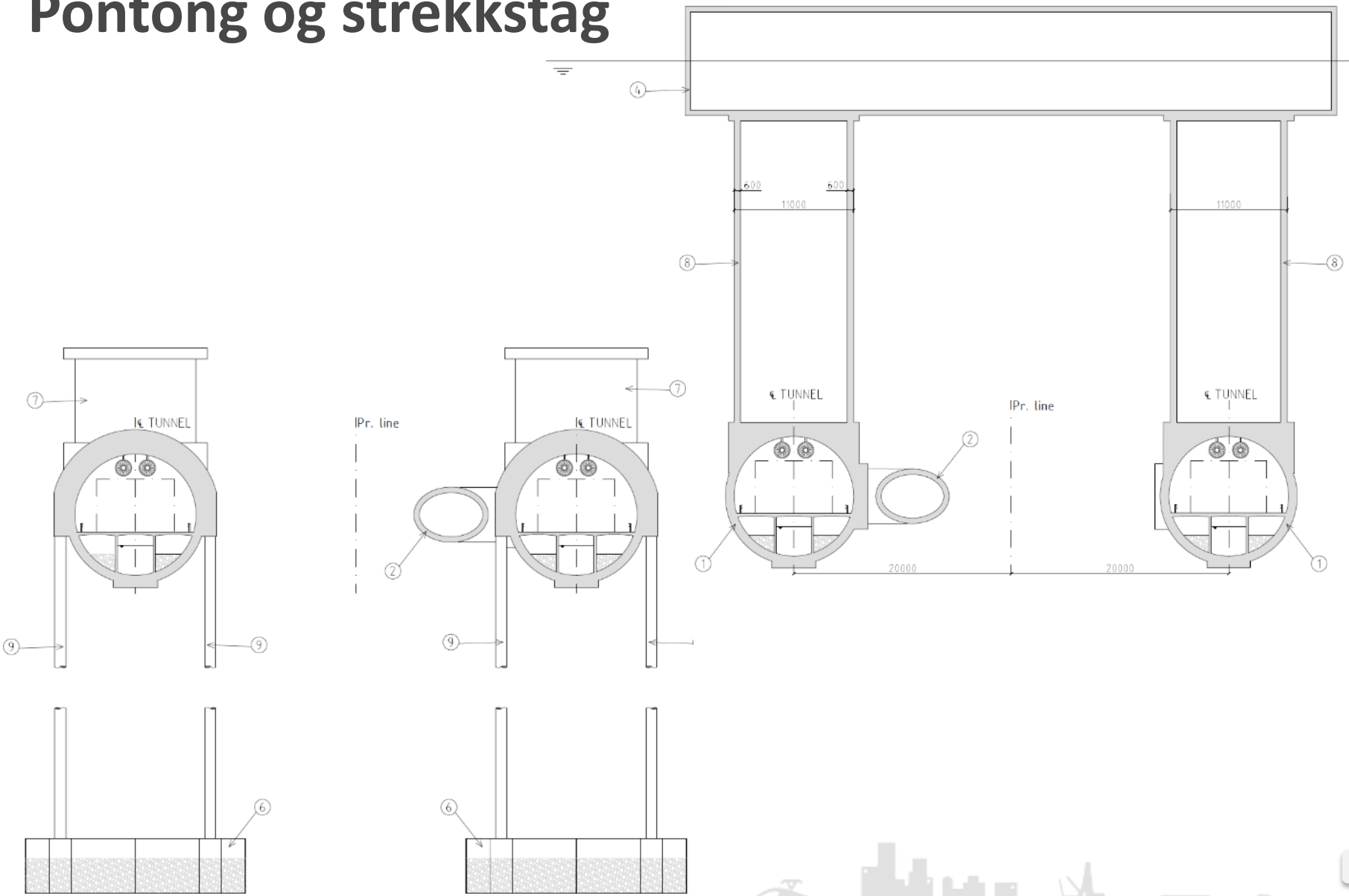


Rør tverrsnitt

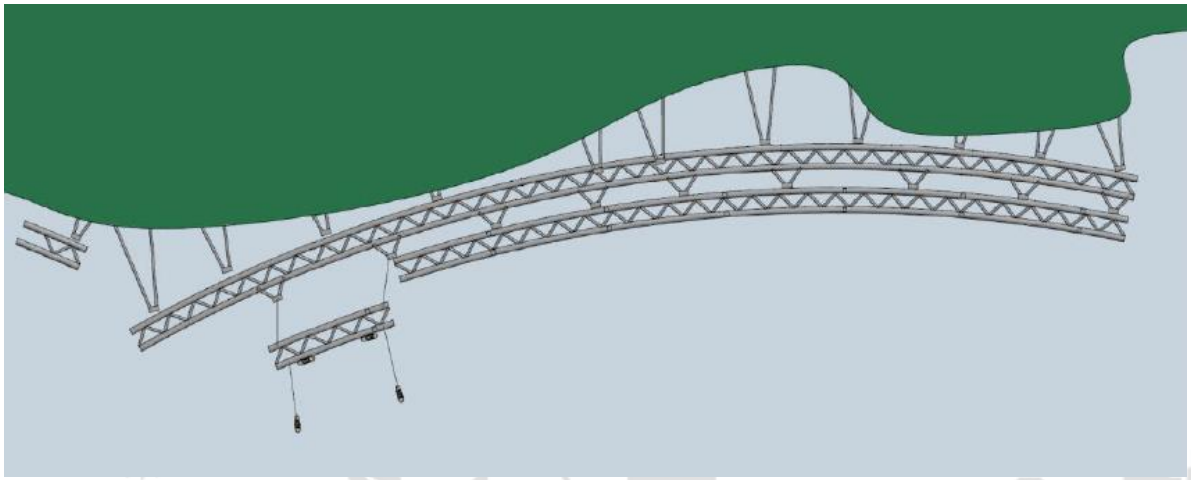


Section A-A
A1=1:100
A3=1:200

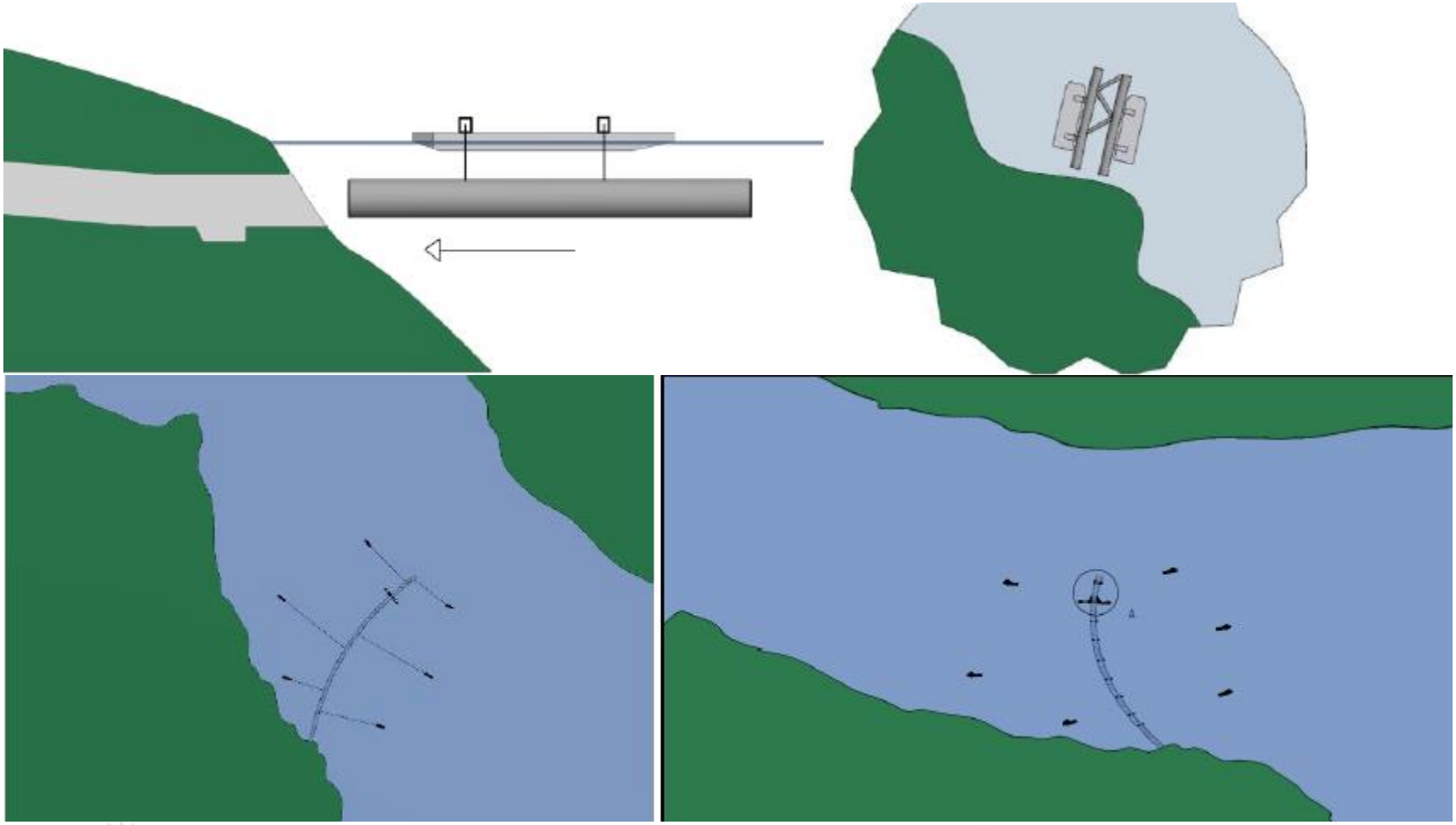
Pontong og strekkstag



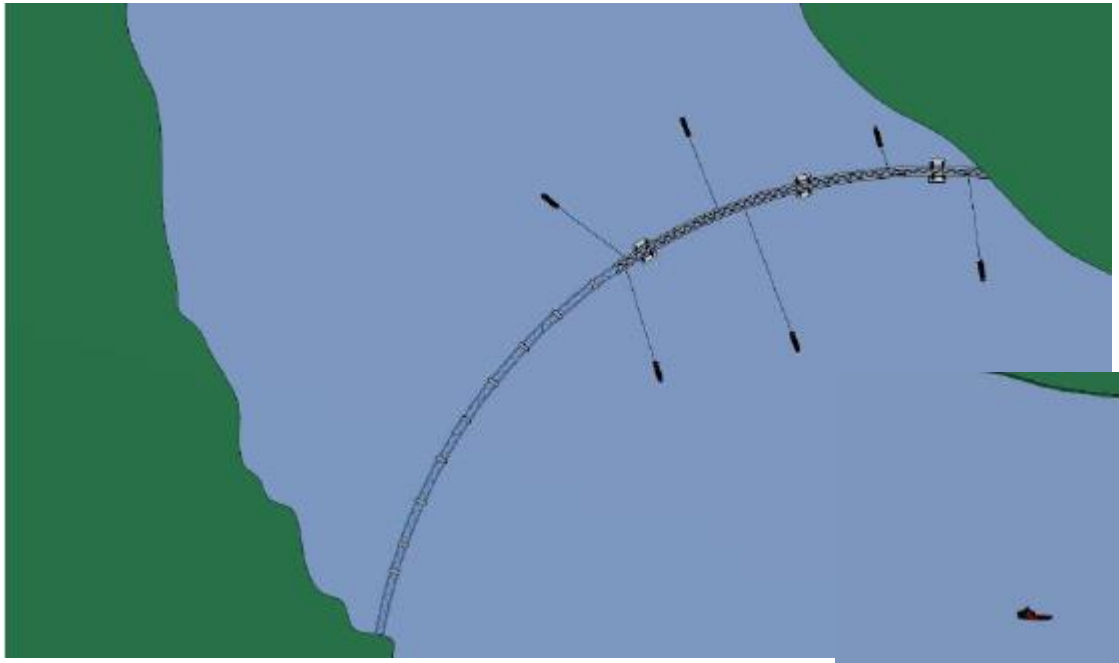
Installasjon (1)

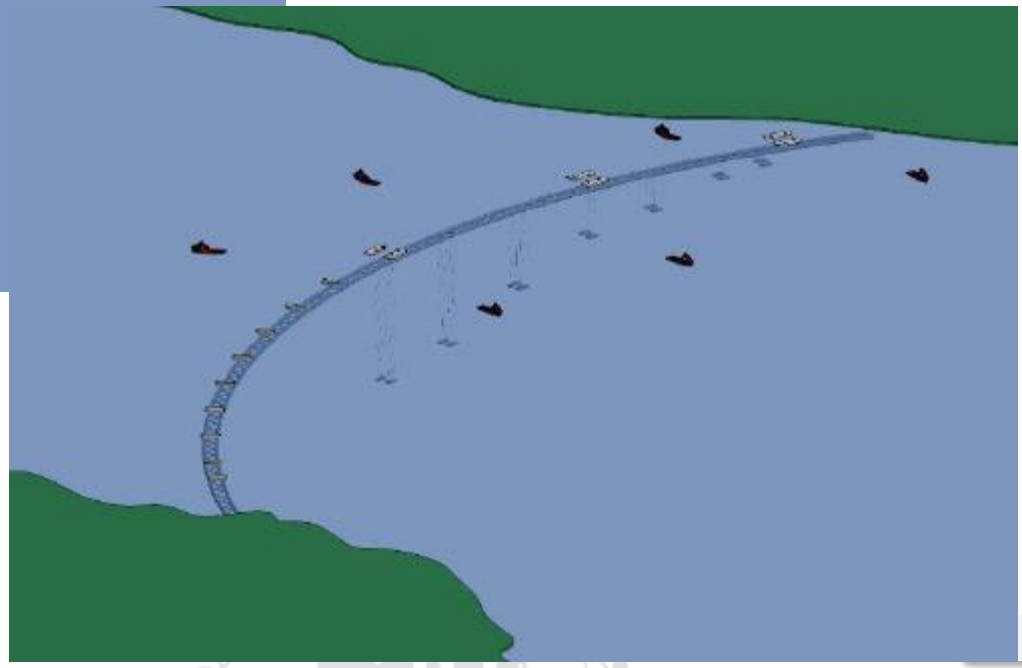


Installasjon (2)



Installasjon (3)



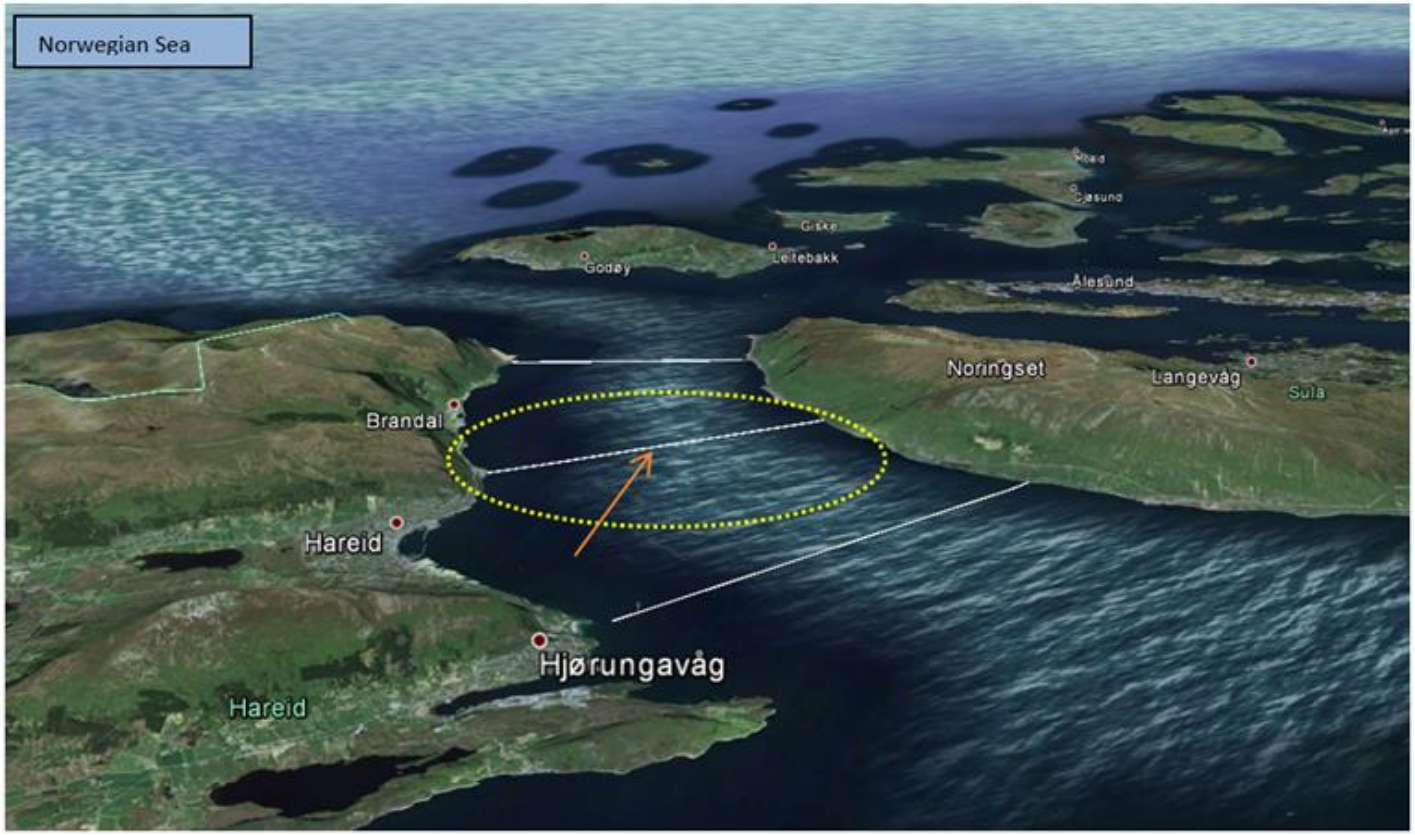


Mengder rørbru – korridor 2

- Betong 420 000 m^3
- Stål 52 000 tonn
- Ballast 215 000 m^3

Hengebru på flytende fundamenter

Hengebru på flytende fundamenter

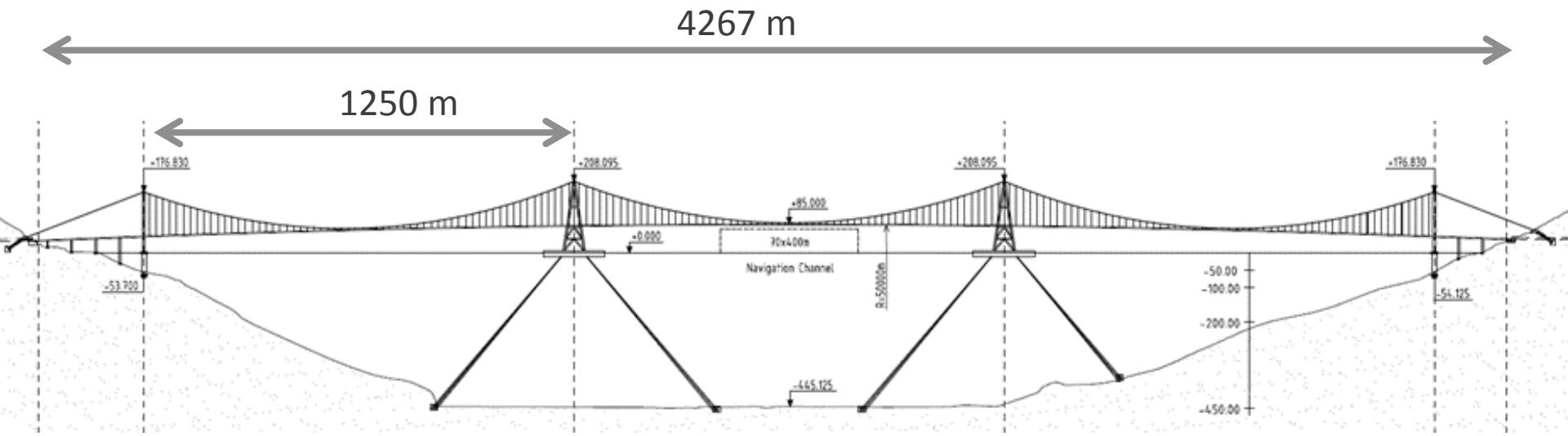


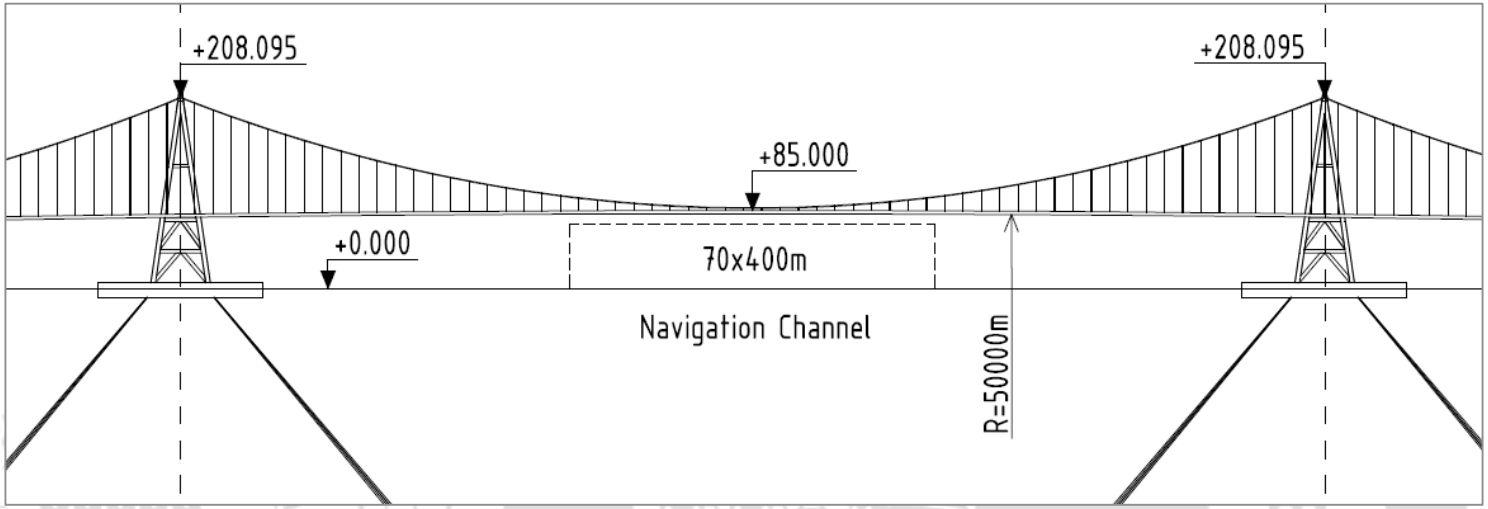
Utfordringer

- Lengde på kryssingen
- Skipsstøt
- Vindlaster og aerodynamisk stabilitet
- Bølger – lange havdønninger
- Minimalt påvirkning på trafikken av vær forhold
- Vedlikeholdsvennlige flytere og forankringssystem

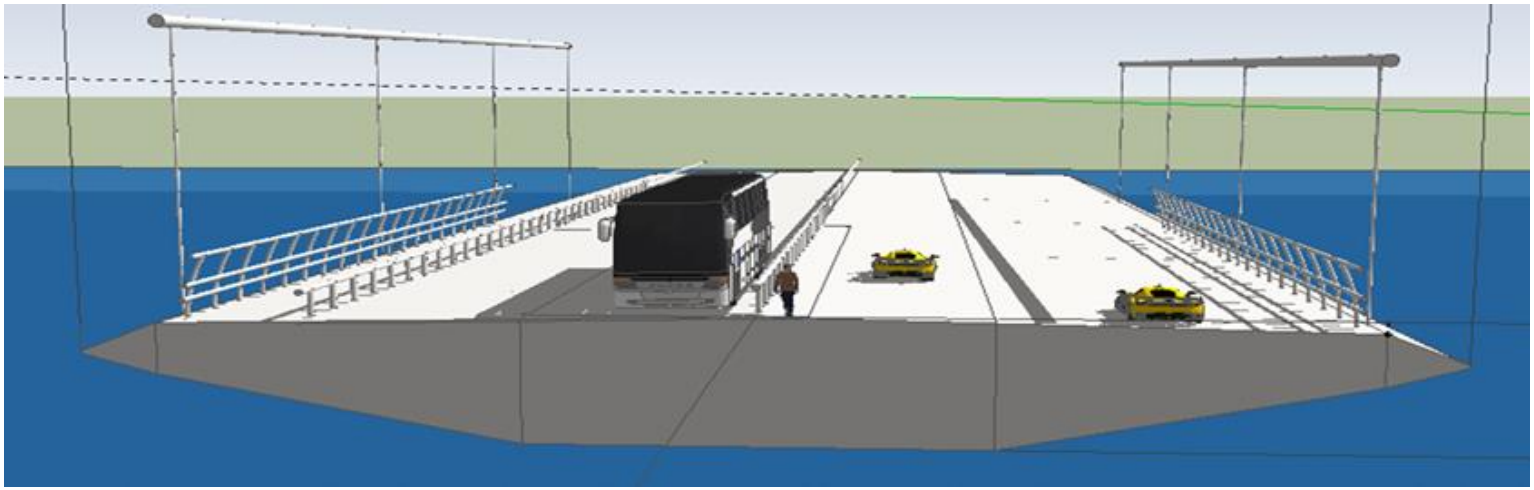
- Kombinasjon av hengebru og flytende fundament

Geometri

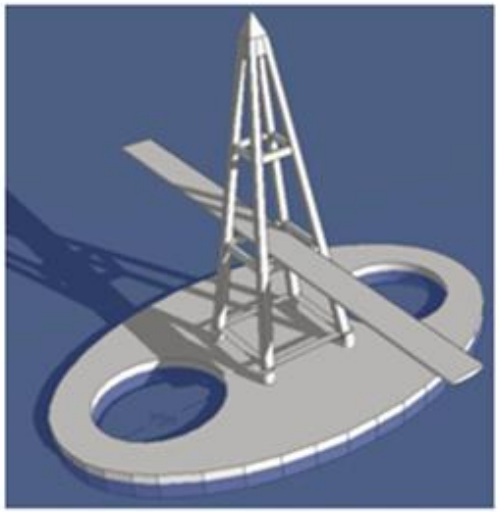

4267 m
1250 m
+176.830
+208.095
+208.095
+176.830
+85.000
+0.000
70x400m
Navigation Channel
R=50000m
-53.700
-50.00
-100.00
-200.00
-450.00
-54.125
-445.125

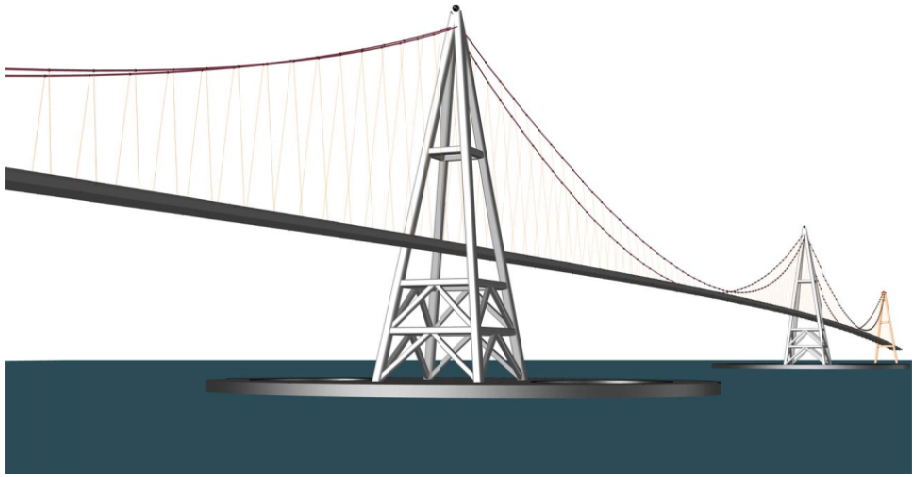

+208.095
+208.095
+85.000
+0.000
70x400m
Navigation Channel
R=50000m

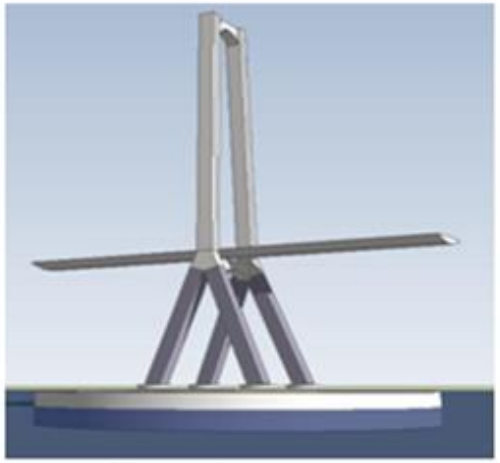
Brutverrsnitt

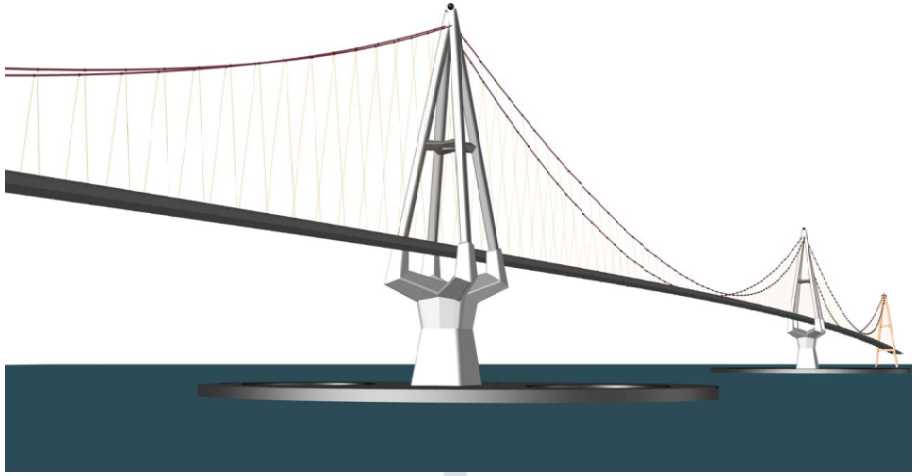


Tårn design

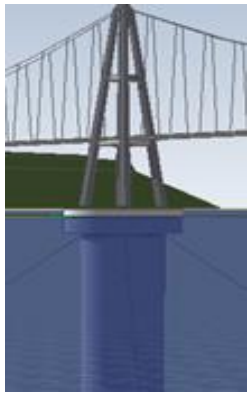
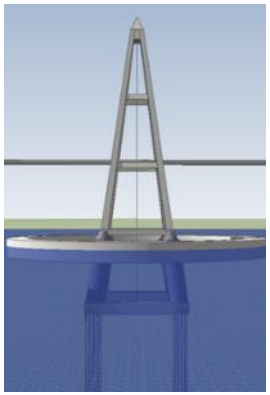
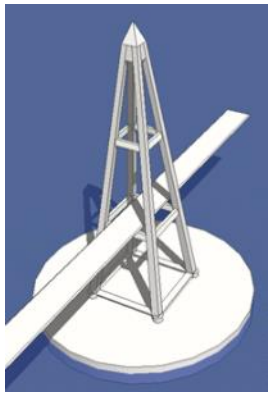
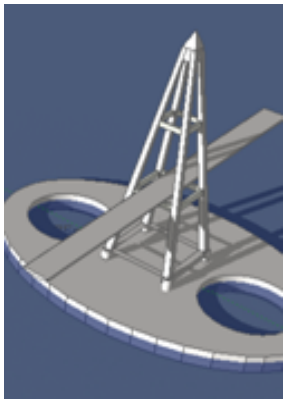






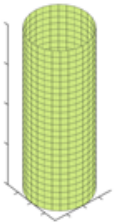


Undersøkte flytere

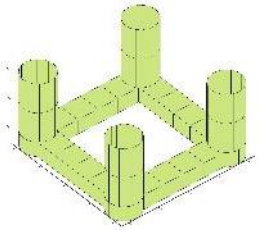
Spar	TLP	Disk	Ellipse
			
Ø 75-80 m Draft 200 m Betong Slakk forankring	Stål TLP Draft 50 m Pontonger 90x12x15 Betong alternativ Strekkstag	Betongflyter Draft 10-15 m Ø 180 m Stram forankring	Betongflyter Draft 10-12 m 300 x 180 m Moonpools Ø 75m Stram forankring

Flytere – Hydrodynamisk egenskaper

Spar



TLP



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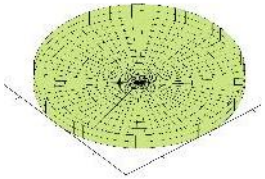
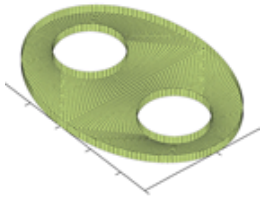
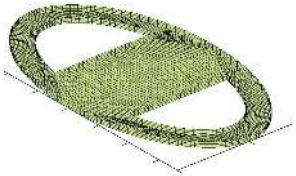
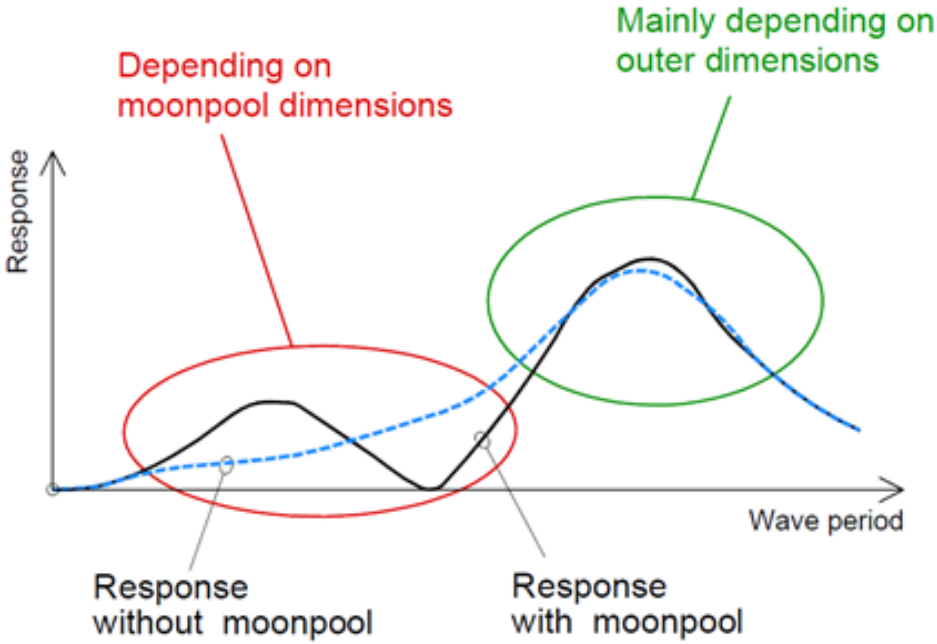


Ellipse



Modifisert ellipse

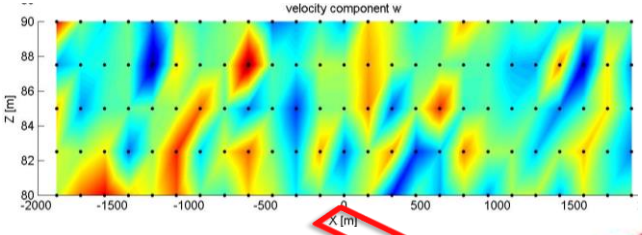


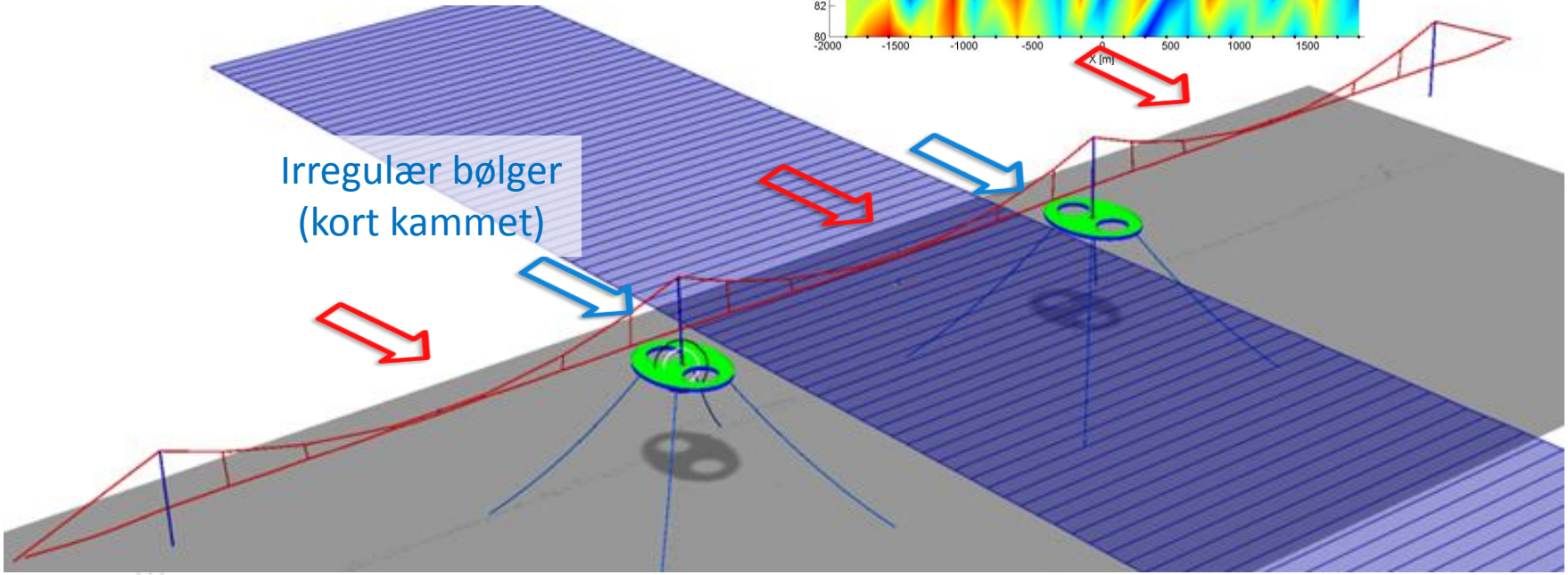


Global respons simuleringer - hydrodynamisk

- Forenklet global struktur modell (Simo&Riflex)
- Dynamikk vind & bølge laster
- Ikke-lineær

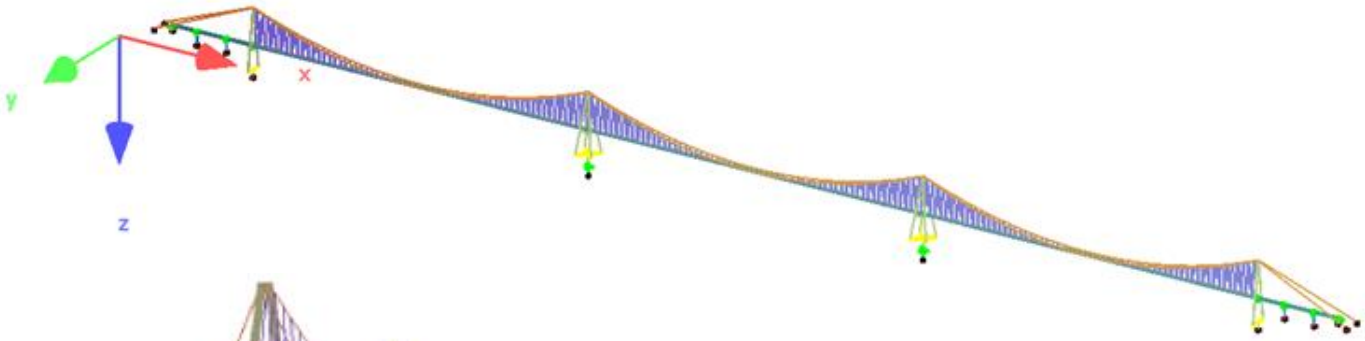
Dynamikk vind hastighet
(turbulent i tid og rom)

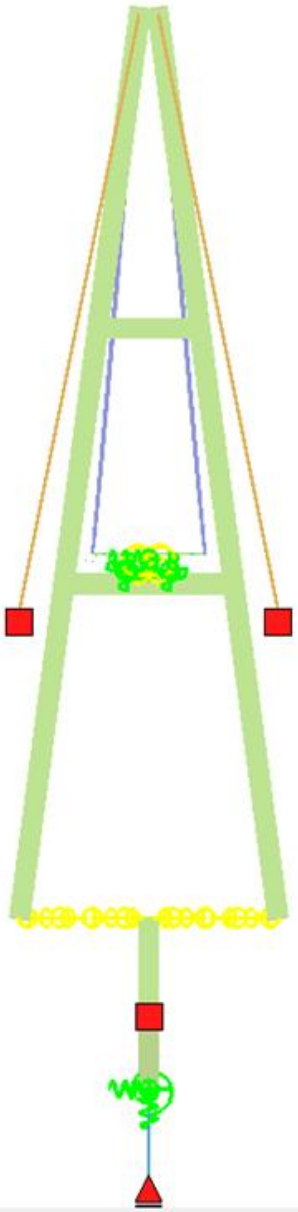




Globalanalyse – Struktur

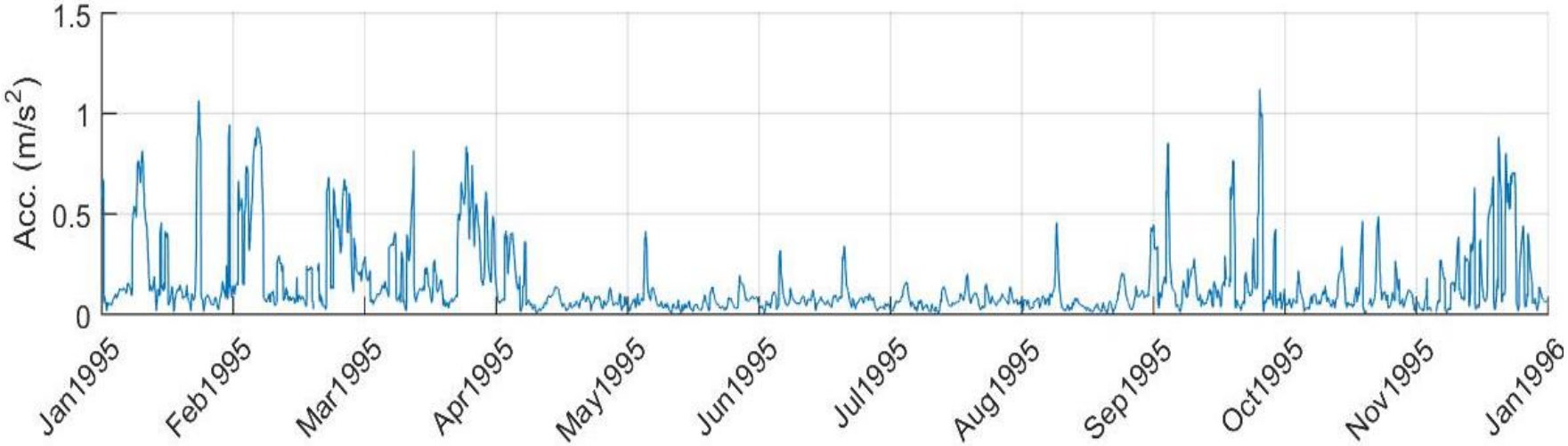
- Detaljert modell i Sofistik
- Dynamisk responssimuleringer



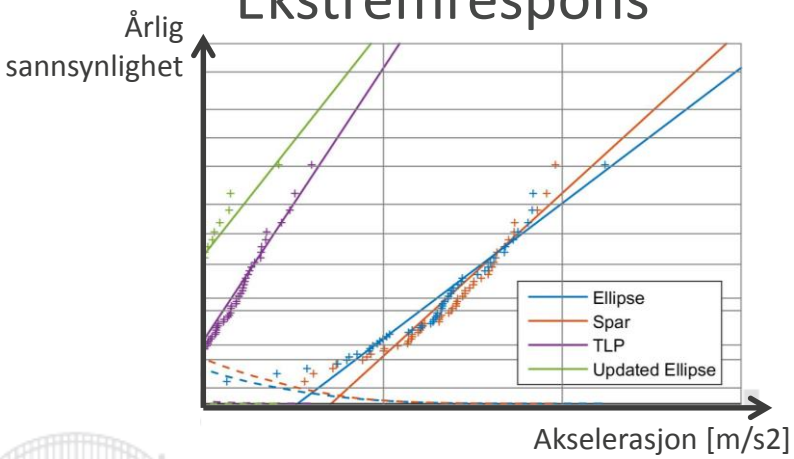


Akselerasjon i midtspenn

Akselerasjon på tverrs av brua i midtspenn pga miljølaster - 50 års tidserier



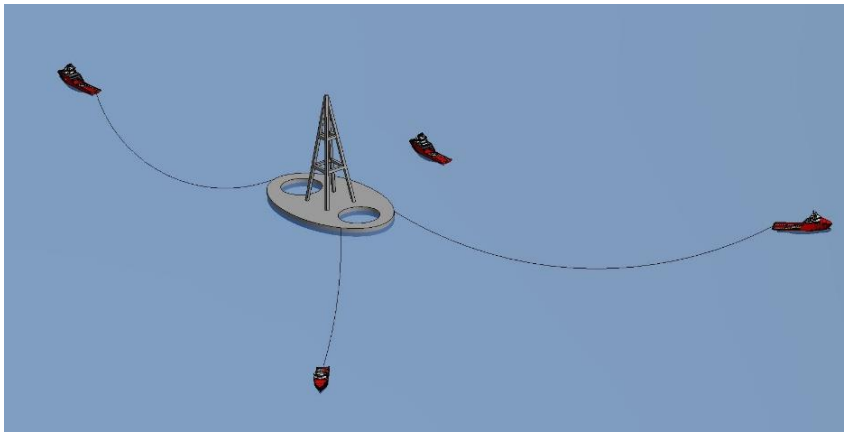
Ekstremrespons

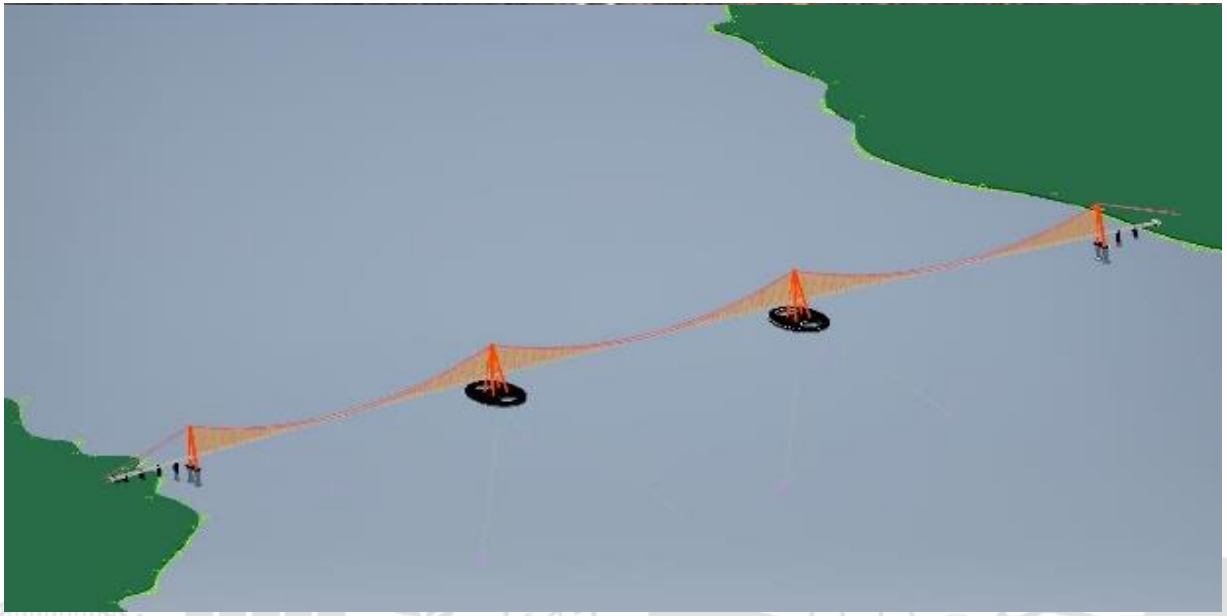


Regularitet

Flyter	Tid med mer enn 0.5 m/s²
Ellipse og Spar	9%
TLP	5%
Modifisert ellipse	2%

Installasjon





Flyter bygges i dokk

Tauing for montasje av pylon

Forankringer plasseres (eg sugeanker)

Flyter og tårn taues til riktig posisjon
Midlertidige forankringer
Posisjonering og forankring

Montasje av hovedkabler

Montasje av bruseksjoner

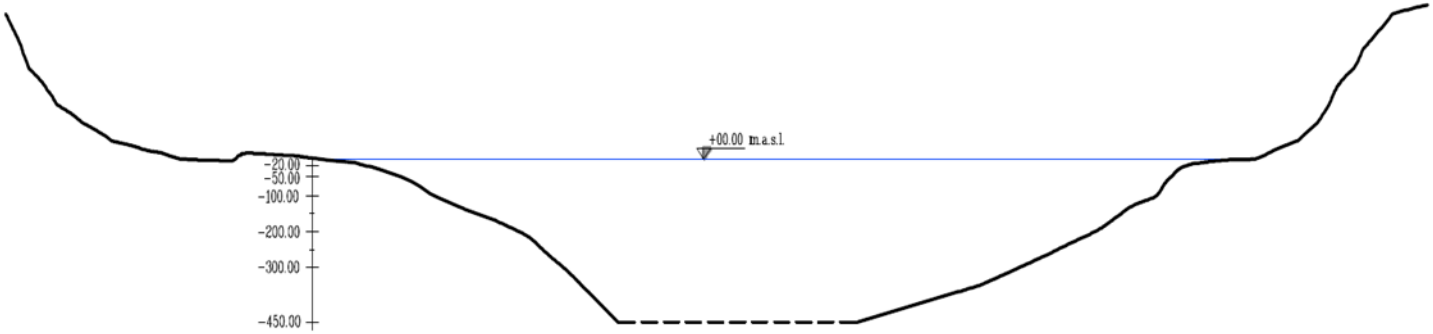
Sammenkobling

Multiconsult

Hengebru

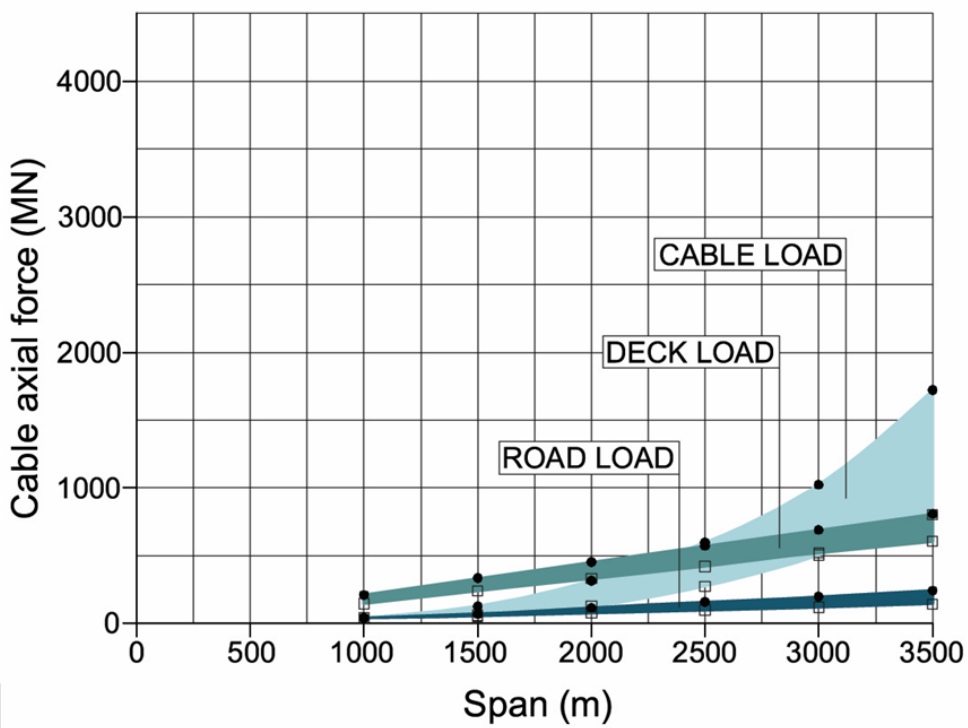
Hengebru

Langevåg
Fiskarstranda
Eidsnes
Mauseidvågen
Solavågen
Sula
Solevågsfjellet
Flø
Brandal
Hareid
Ulstein
Hjørungavåg
Grimstadvatn
Ulsteinvik
Barstadvik
Hareidlandet

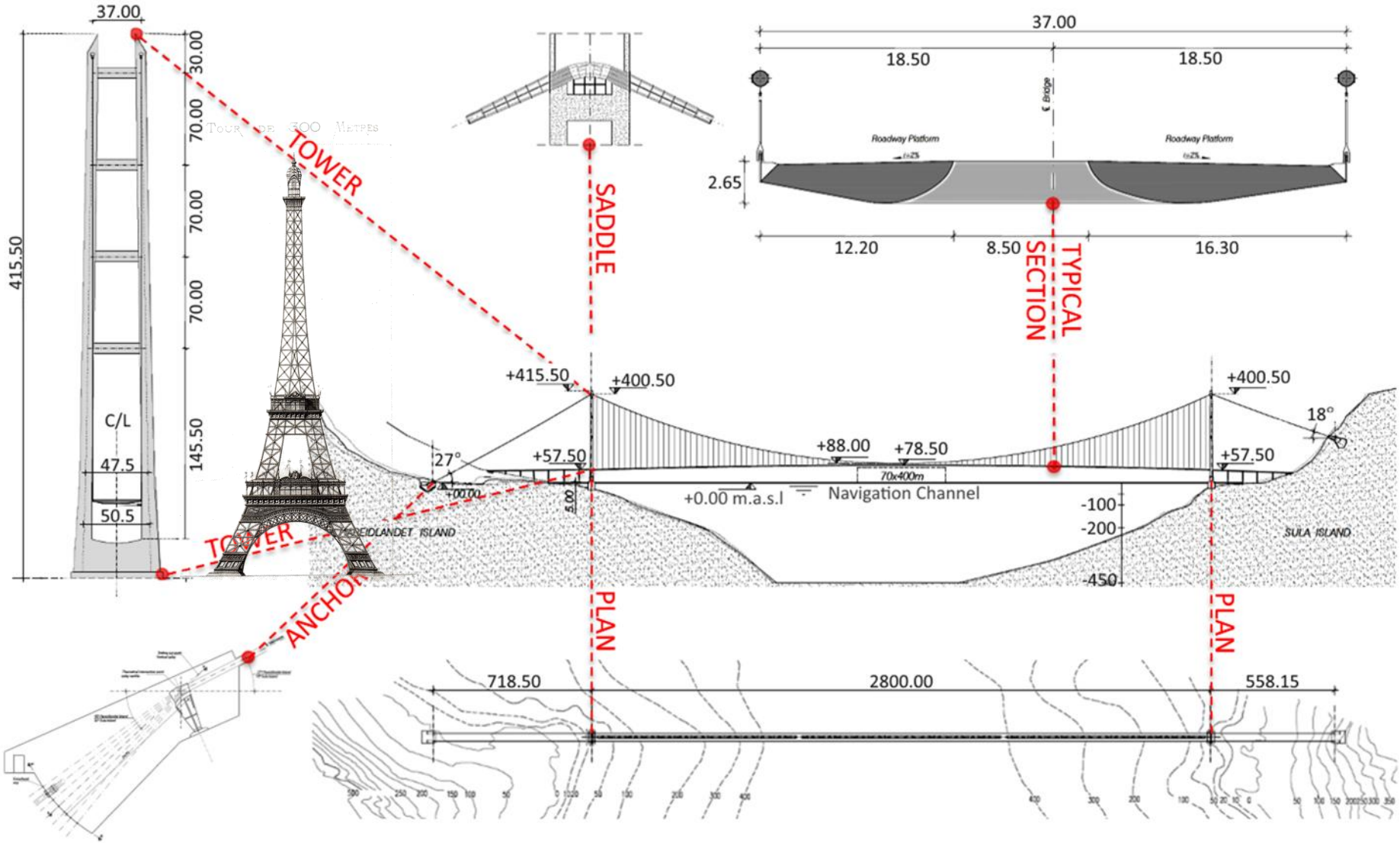

+00.00 m.a.s.l.
-20.00
-50.00
-100.00
-200.00
-300.00
-450.00

Utfordringer

- Miljølaster – vind og bølger
- Spennvidde
- Holde kabelvekten så lav som mulig



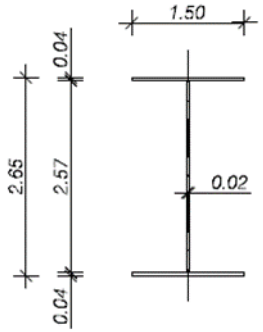
Geometri


37.00
30.00
70.00
70.00
70.00
145.50
415.50
C/L
47.5
50.5
TOWER
TOWER
ANCHOR
SADDLE
37.00
18.50
18.50
Roadway Platform
Roadway Platform
2.65
12.20
8.50
16.30
TYPICAL SECTION
+415.50
+400.50
+400.50
18°
27°
+57.50
+57.50
+88.00
+78.50
70x400m
+0.00 m.a.s.l
Navigation Channel
-100
-200
-450
SULA ISLAND
PLAN
PLAN
718.50
2800.00
558.15

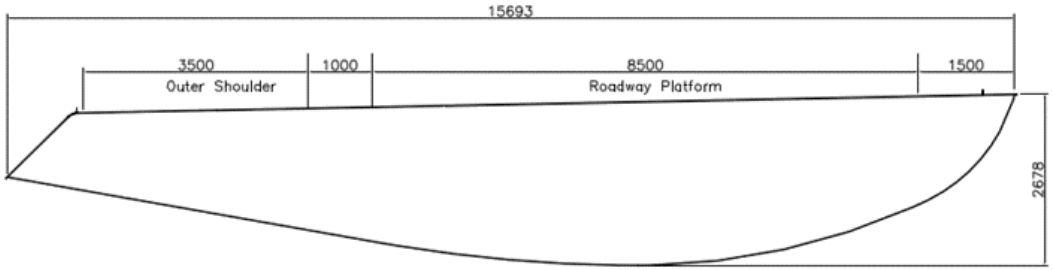
Tverrsnitt

30 000 tonn stål

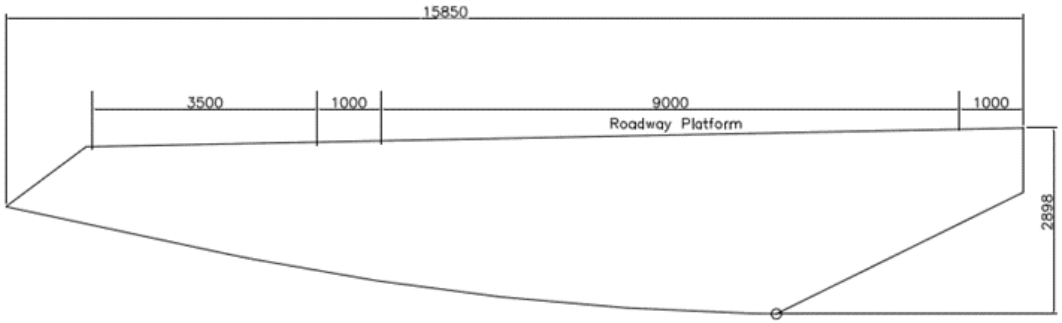
Section DD - scale 1:50

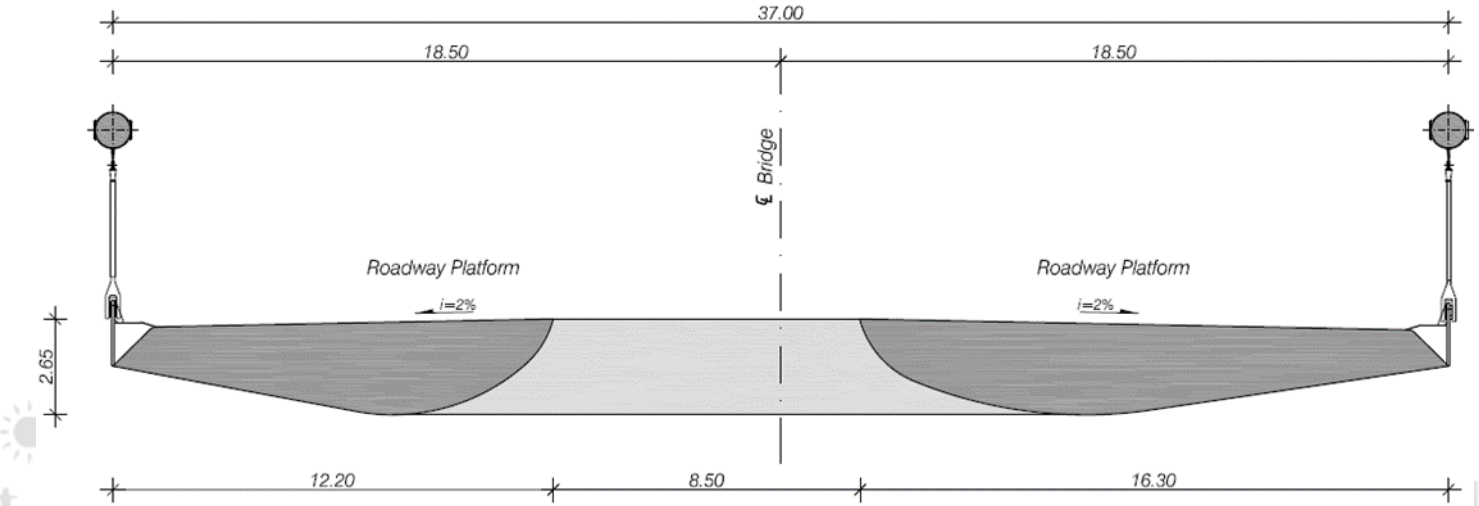


SULAFJORDEN – SOLUTION NO.1



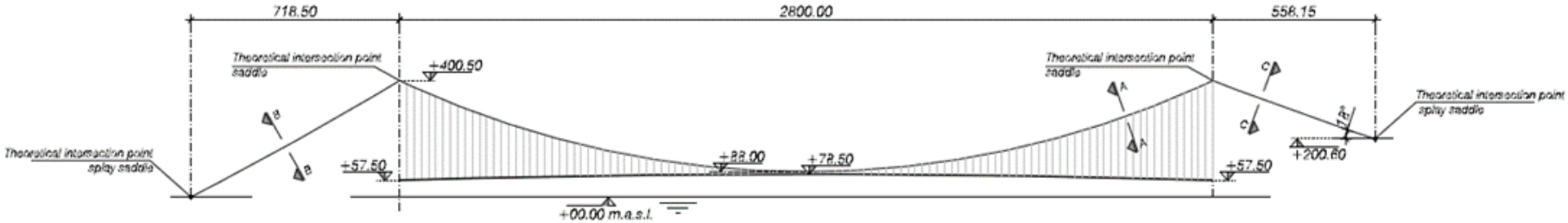
SULAFJORDEN – SOLUTION NO.2



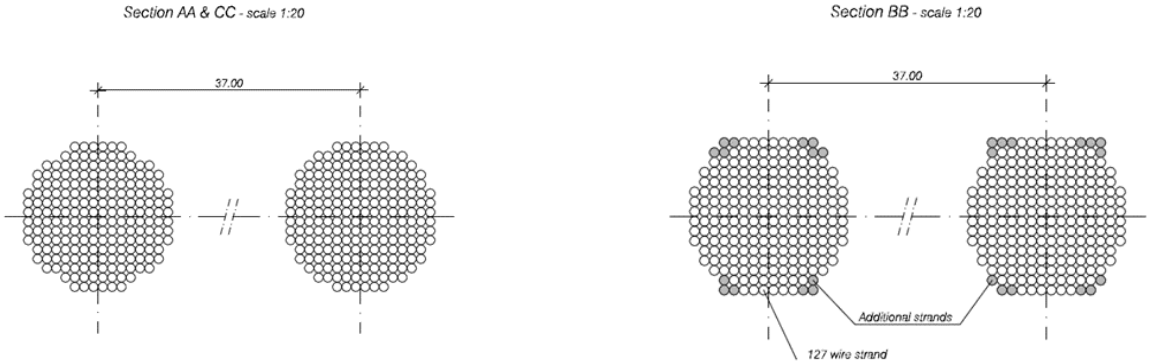


Kabler

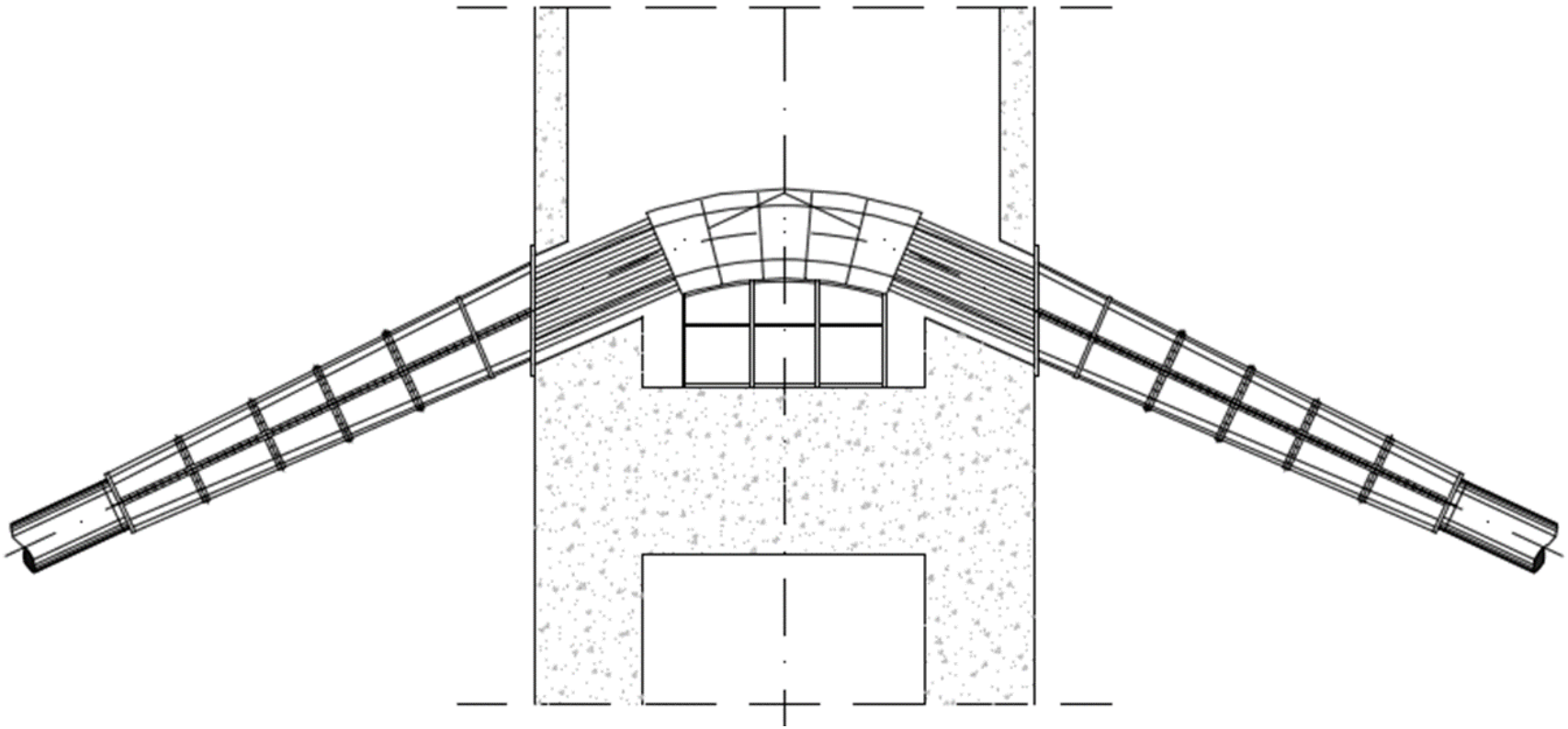
42 000 tonn kabler og 1400 tonn hengestenger



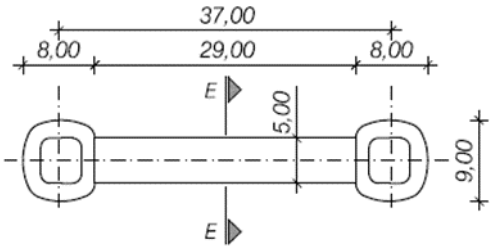
127-tråder-PPWS med ekstra trader på Hareidsiden



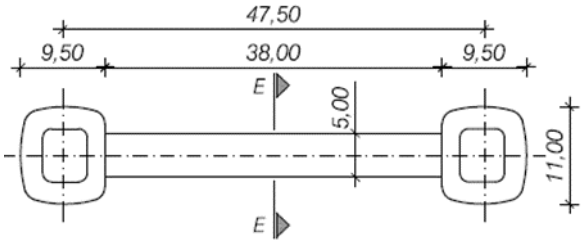
Sadel

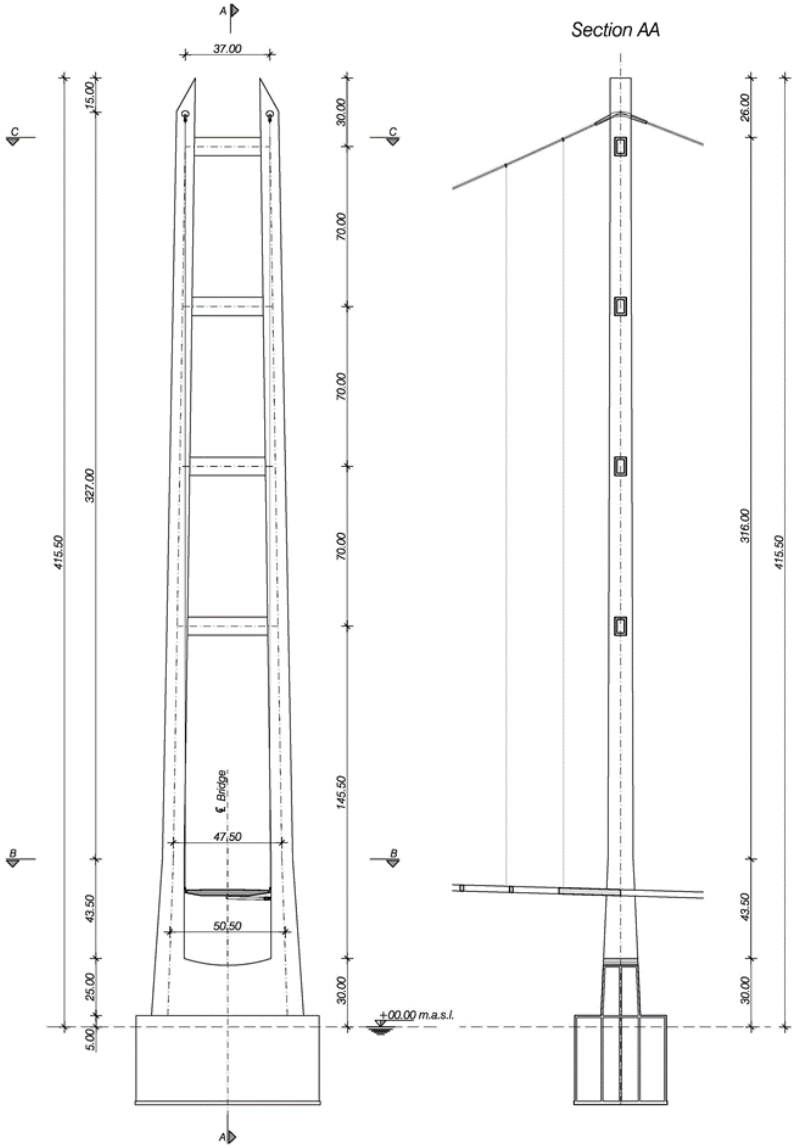


Tårn

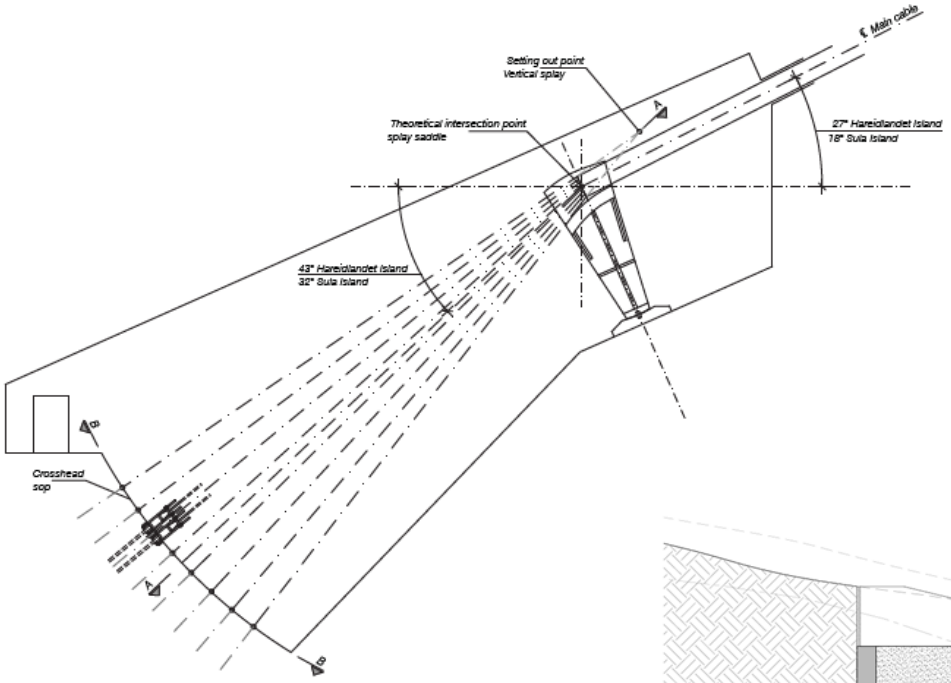


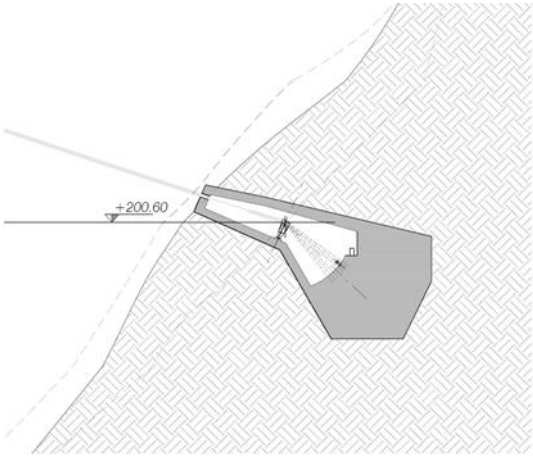
47 000 m^3 betong og
6000 tonn armering

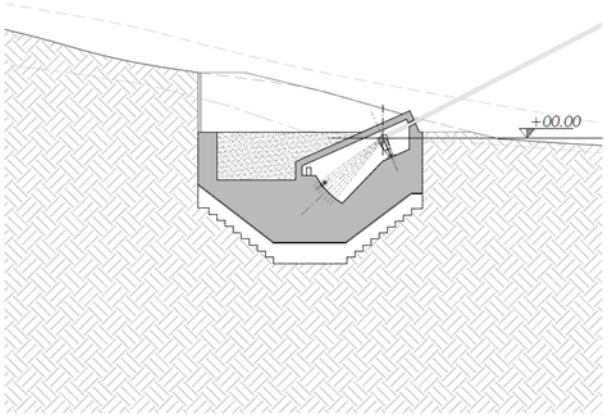




Kabelforankringer

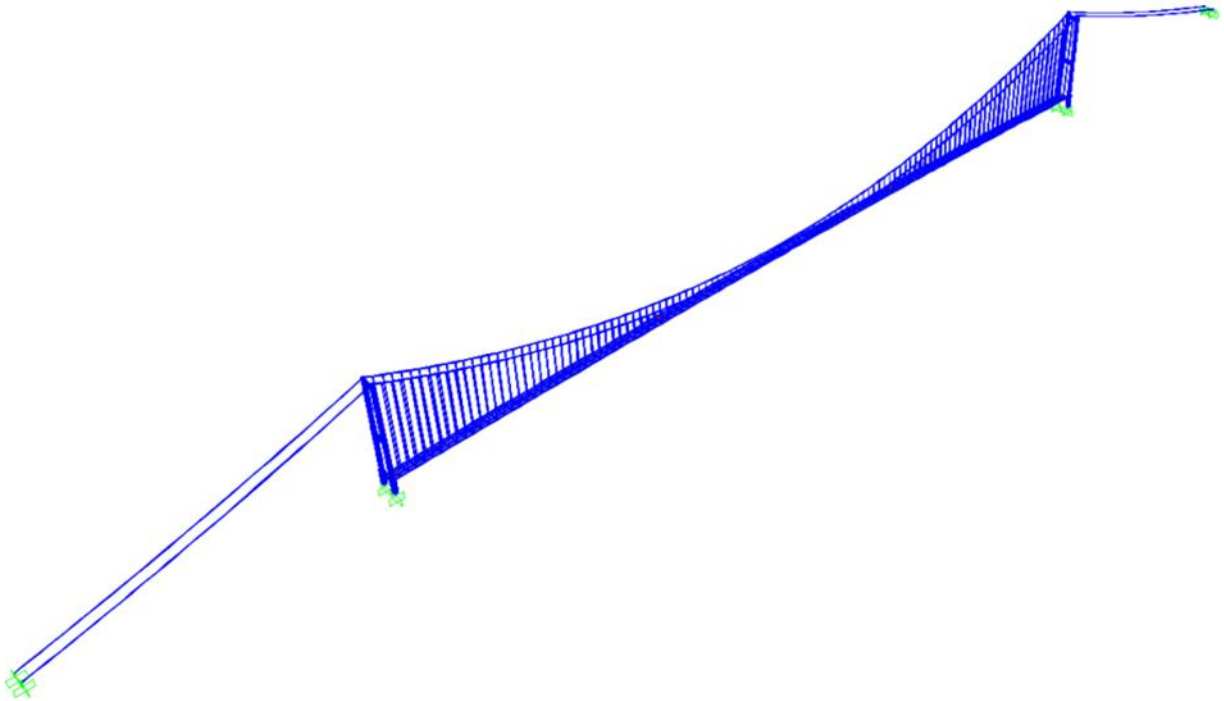






Analyser og design

- Global analyse SAP2000



Sensitivitetsanalyser

1. Kabelkvalitet
2. Symmetrisk tverrsnitt (to brede bokser)
3. Pilhøyde kabler
4. Asfalttykkelse

Solution no.	Cable strength	Girder arrangements	Cable sag	Pavement thickness	Cable quantities	Changes from reference sol.
-	MPa	Sym/Non Sym	-	mm	Tons	Tons
1	1860	Non sym	1/9	80 mm	41754	/
2	**1960**	Non sym	1/9	80 mm	39345	- 2409
3*	1860	**Sym**	1/9	80 mm	44426	+ 2672
4	1860	Non sym	**1/10**	80 mm	44990	+ 3236
5	1860	Non sym	1/9	**40 mm**	38706	- 3048

* Symmetrisk tverrsnitt medfører også en økt stålvekt på dekket (3600 tonn)