AAS-JAKOBSEN

Vindtekniske problemstiller for Chacao Bridge i Chile

01.10.2014

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Innhold

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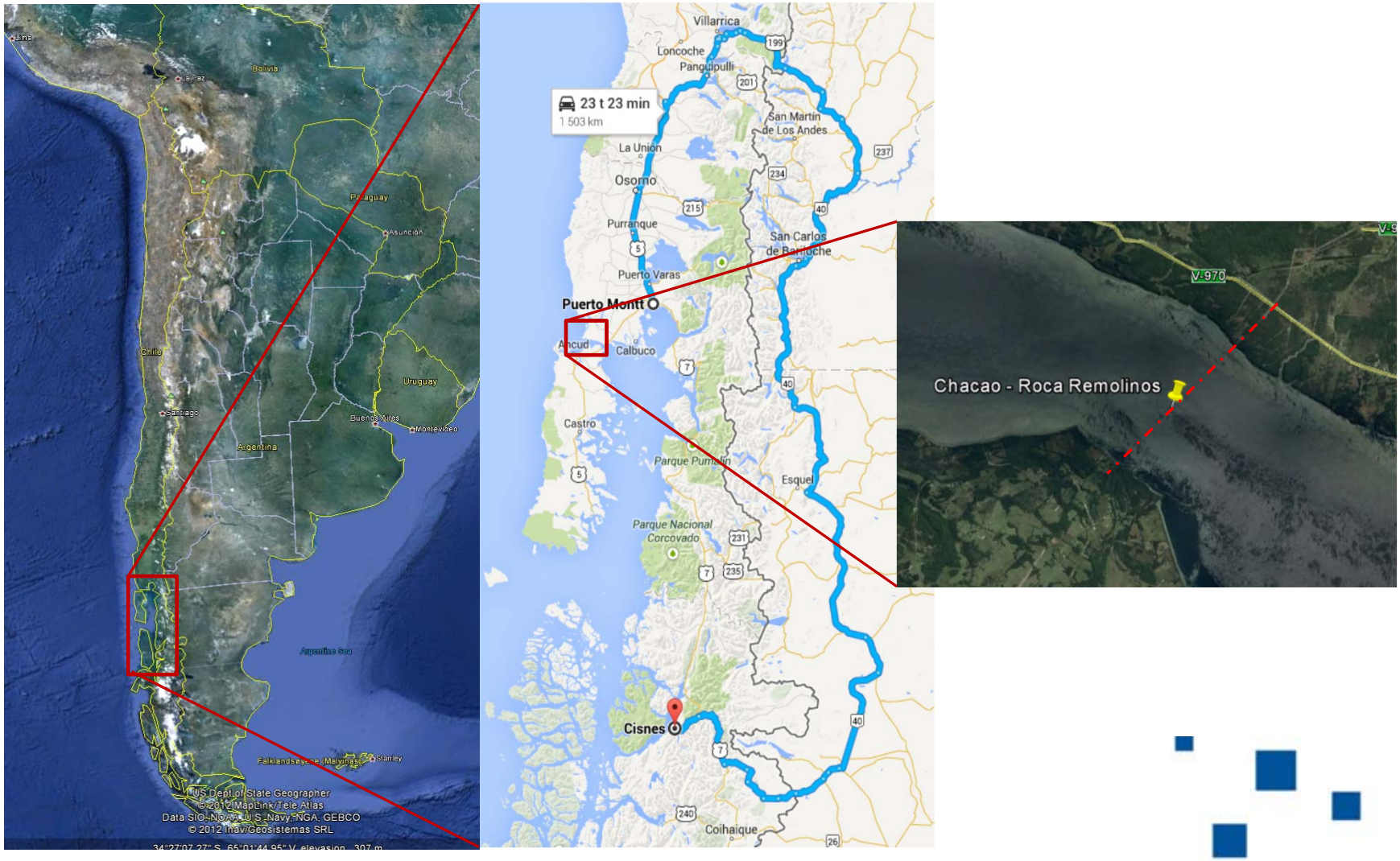
- Chacao prosjektet – historikk
- Myndighetenes krav
- Viktige laster
- Vindtekniske problemstillinger
  - **Vindmålinger**
  - **Vindtunnelforsøk**
  - **Spesielle problemstillinger**
  - **Beregninger**

Plassering



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Historisk tilbakeblikk

- Prosjekt i 2001 og 2005.
- Total lengde: 2750m. Seilingsløp: 600mx60m
- Hengebru med tre tårn:
  - Tre tårn: 157m, 175m, 199m
  - Spenn: 1055, 1155 + 324m sidespenn
  - 2005: EPCO: VINCI construction
    - Hochtief, American Bridge, Besalco and Tecsa.

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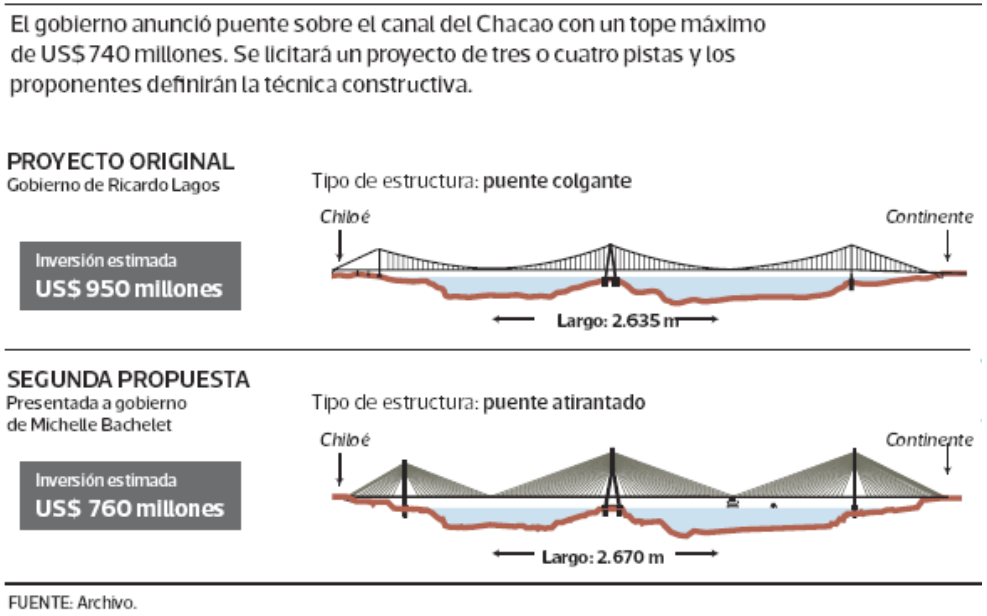
- Re-vitalisering I 2012.
- Kontaktet av Hyundai
- Systra



- Referanser.
- Prosjekter i Sør Korea.
- Prosjekter For Hyundai.
- Nr 2 på Izmit Bay Bridge.

- Tilbudsinnlevering

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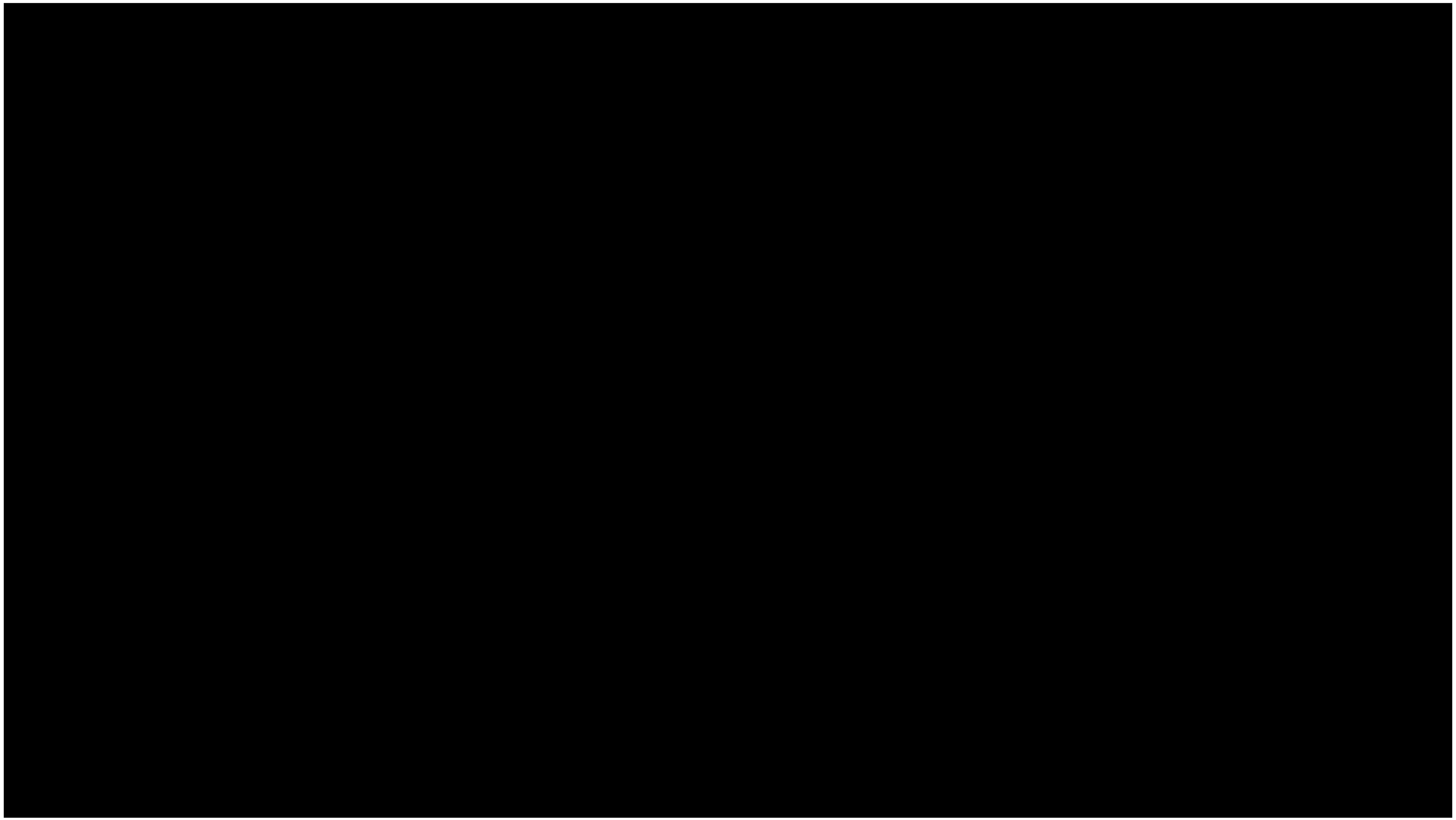
Chacao Bridge



Organisering

Ministerio de Obras Públicas

Gobierno de Chile

Consorcio puente chacao

HYUNDAI ENGINEERING & CONSTRUCTION

oas

SYSTRA

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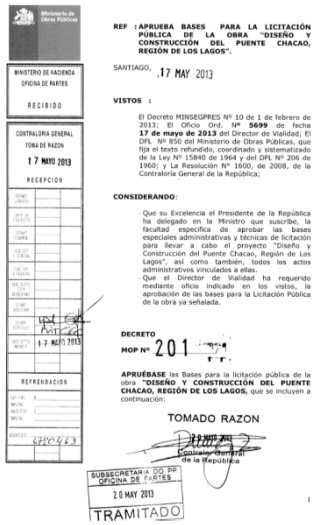
Design Basis - prosjekteringsforutsetninger

1. Oppdragsgivers krav (ITB)
2. AASHTO LRFD 2013
3. Manual de Carreteras (Chilensk kode)

=> Design Basis



Ministerio de Obras Públicas

MINISTERIO DE HACIENDA
OFICINA DE PARTES
RECIBIDO

CONTRALORIA GENERAL
TOMA DE RAZON
17 MAYO 2013
RECEPCION

REFRENDACION

REF : APRUEBA BASES PARA LA LICITACIÓN PÚBLICA DE LA OBRA "DISEÑO Y CONSTRUCCIÓN DEL PUENTE CHACAO, REGIÓN DE LOS LAGOS".

SANTIAGO, 17 MAY 2013

VISTOS :

El Decreto MINSEGPRES Nº 10 de 1 de febrero de 2013; El Oficio Ord. **Nº 5699** de fecha **17 de mayo de 2013** del Director de Vialidad; El DFL Nº 850 del Ministerio de Obras Públicas, que fija el texto refundido, coordinado y sistematizado de la Ley Nº 15840 de 1964 y del DFL Nº 206 de 1960; y La Resolución Nº 1600, de 2008, de la Contraloría General de la República;

CONSIDERANDO:

Que su Excelencia el Presidente de la República ha delegado en la Ministro que suscribe, la facultad específica de aprobar las bases especiales administrativas y técnicas de licitación para llevar a cabo el proyecto "Diseño y Construcción del Puente Chacao, Región de Los Lagos", así como también, todos los actos administrativos vinculados a ellas.

Que el Director de Vialidad ha requerido mediante oficio indicado en los vistos, la aprobación de las bases para la Licitación Pública de la obra ya señalada.

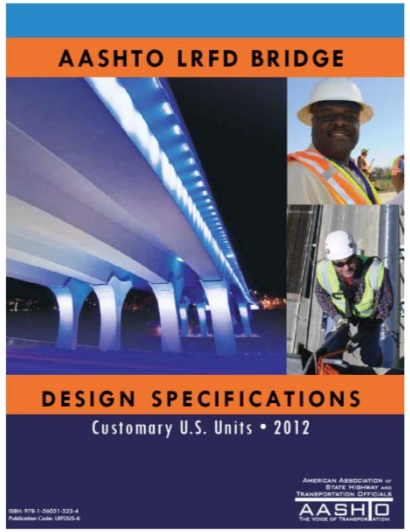
DECRETO
MOP Nº 201

APRUÉBASE las Bases para la licitación pública de la obra **"DISEÑO Y CONSTRUCCIÓN DEL PUENTE CHACAO, REGIÓN DE LOS LAGOS,** que se incluyen a continuación:

TOMADO RAZON

Contralor General de la República

SUBSECRETARIA DO. PP.
OFICINA DE PARTES
20 MAY 2013
TRAMITADO



REPUBLICA DE CHILE
MINISTERIO DE OBRAS PUBLICAS
DIRECCION GENERAL DE OBRAS PUBLICAS
DIRECCION DE VIALIDAD

EVALUACION DE PROYECTOS
VIALES INTERURBANOS

MANUAL DE
CARRETERAS

VOLUMEN 1
TOMO II

RICARDO LAGOS ESCOBAR
Ministro de Obras Públicas

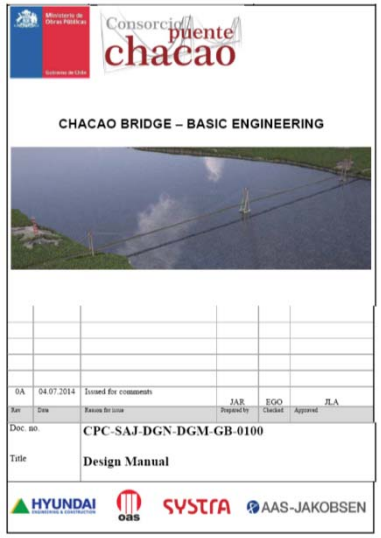
JUAN LOBOS DIAZ
Ing. Director General de OO.PP.

YANKO VILICIC RASMUSSEN
Ing. Director de Vialidad

SONIA MORALES PINTO
Ing. Subdirectora de Desarrollo

MARIA INES MARTINEZ
Ing. Jefa Depto Planes y Programas

JUNIO 1997



Ministerio de Obras Públicas
Consorcio puente chacao

CHACAO BRIDGE – BASIC ENGINEERING

Rev	Date	Reason for issue	Prepared by	Checked	Approved
0A	04.07.2014	Issued for comments	JAR	EGO	JLA

Doc. no. CPC-SAJ-DGN-DGM-GB-0100

Title Design Manual

HYUNDAI oas SYSTRA AAS-JAKOBSEN

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Utfordringer

- Vind
- Strøm(byggetilstand)
- Trafikk
- Temperatur
- Jordskjelv
- Skipsstøt
- Tsunami

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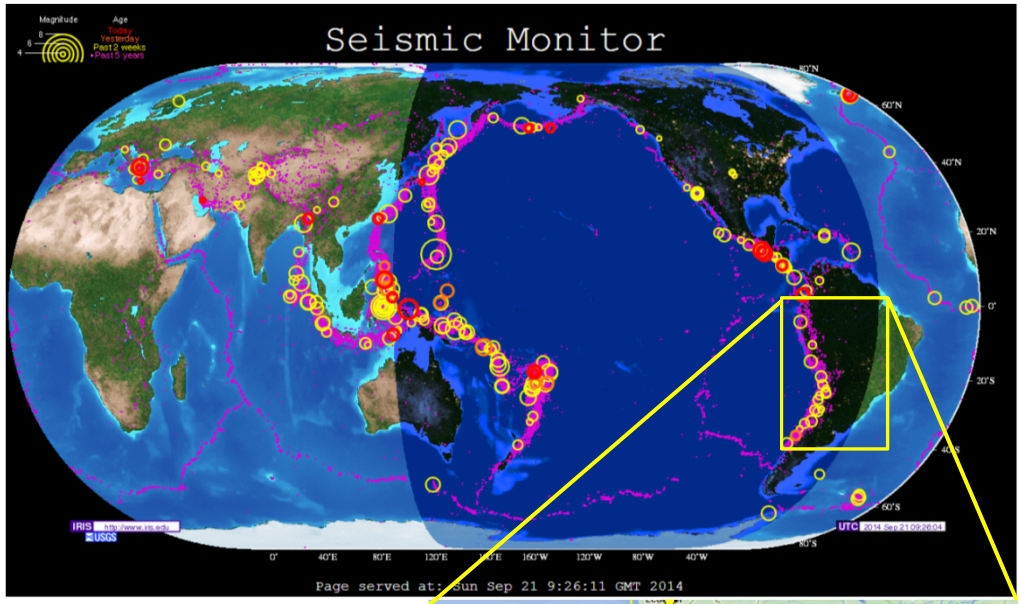
Jordskjelv

- Jordskjelvregistreringer
- Valdiva 1960
  - **Tsunami**
- Designjordskjelv:
  - **1000 år**
- Dimensjonerende for
  - **Peler**
  - **Fundamenter**
  - **Tårn**



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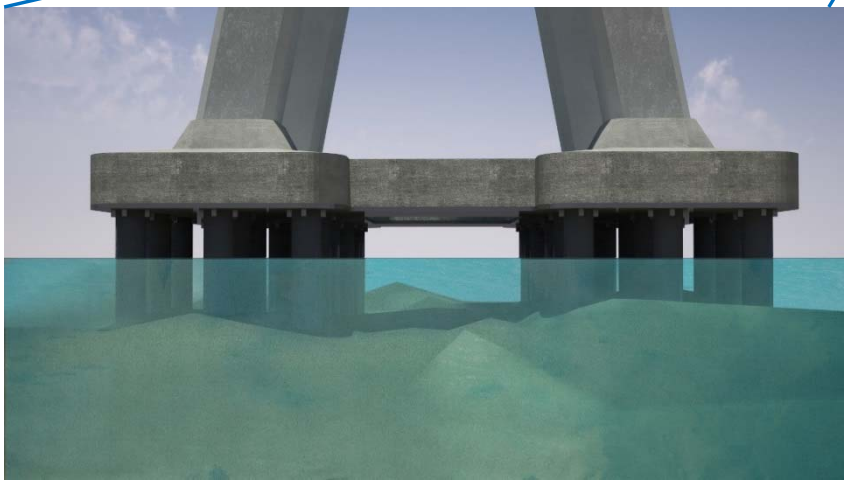
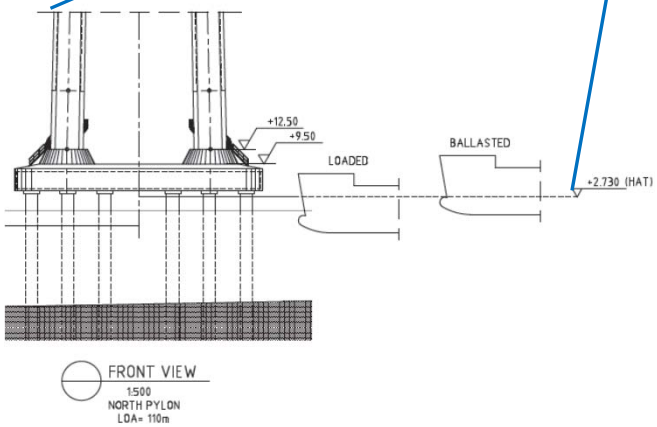
Skipsstøt





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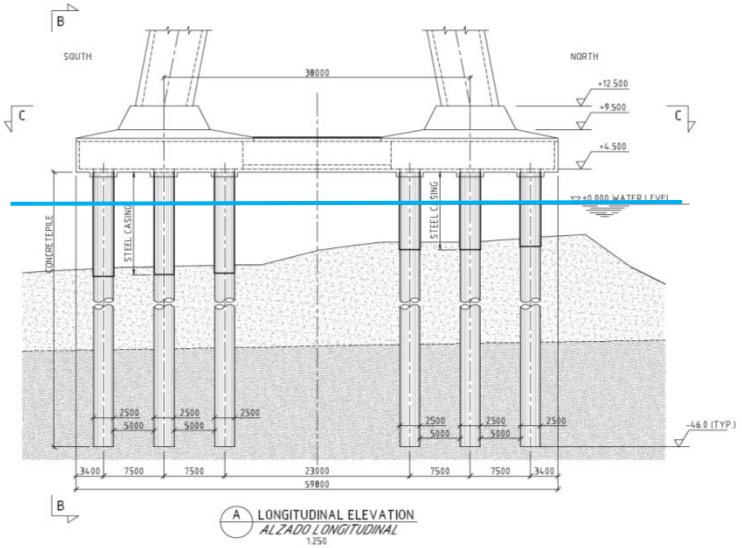
Strøm i byggetilstanden



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Vind - intro

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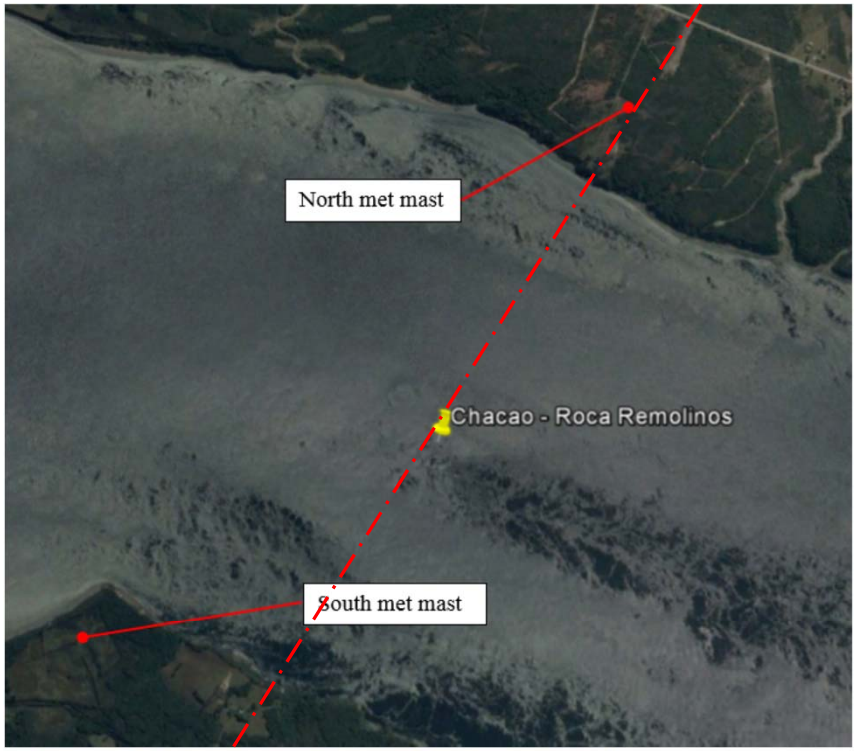
Vindtekniske utfordringer

- Vind dimensjonerende => kontroll på vindoppførsel
- Overordnet mål: Krefter og oppførsel med tilstrekkelig sikkerhet.
- Delmål:
  - **Dokumentere vindklima**
  - **Dokumentere aerodynamisk stabilitet**
  - **Korrekte input parametere til buffeting analyse**
  - **Stabilitet i byggetilstand**
  - **Kabeleffekter**
  - **Oppfylle kundens krav**

Vindmålinger

- Krav:
  - **Middelvind**
  - **Vindrose**
  - **3s-1time**
  - **Vindspektra**
  - **Coherens**
- Spesifikasjoner av måleprogram



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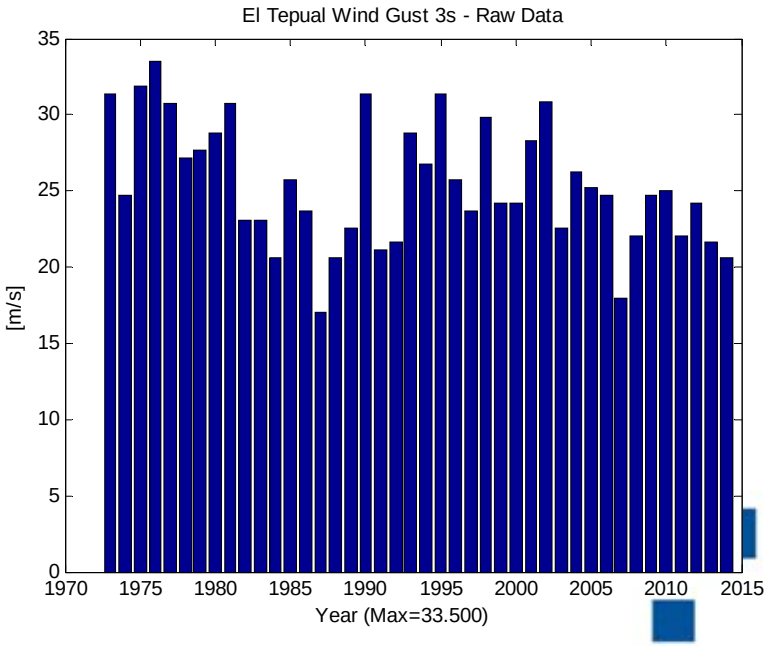
Ekstremverdiestimering

- El Tepual
- Kobling brusted – målinger
- 3s Gust speed



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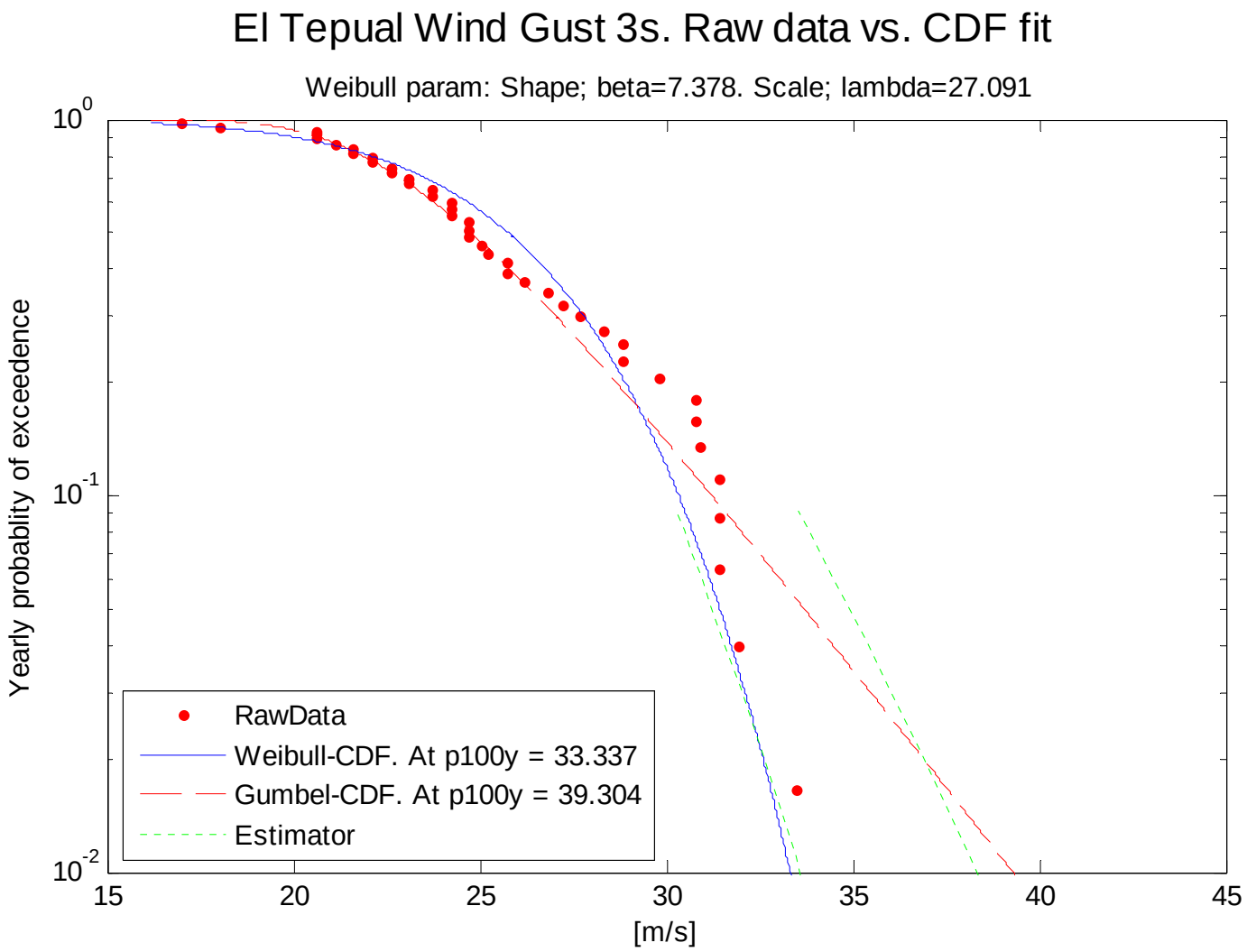
Ekstremverdiestimering



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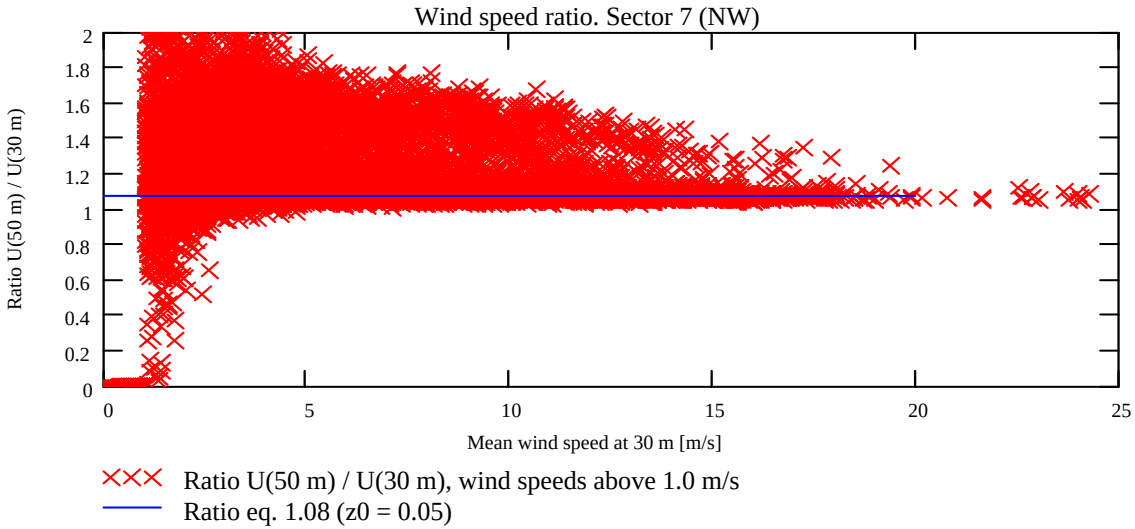
Resultater - middelvindprofil

- Ingeniørmodell, to målenivåer

$$V_{10}(z) = V_b \cdot k_t \cdot \ln(\frac{z}{z_0}) \qquad k_t = \frac{1}{\ln(\frac{10}{z_0})}$$



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Resultater - vindturbulens

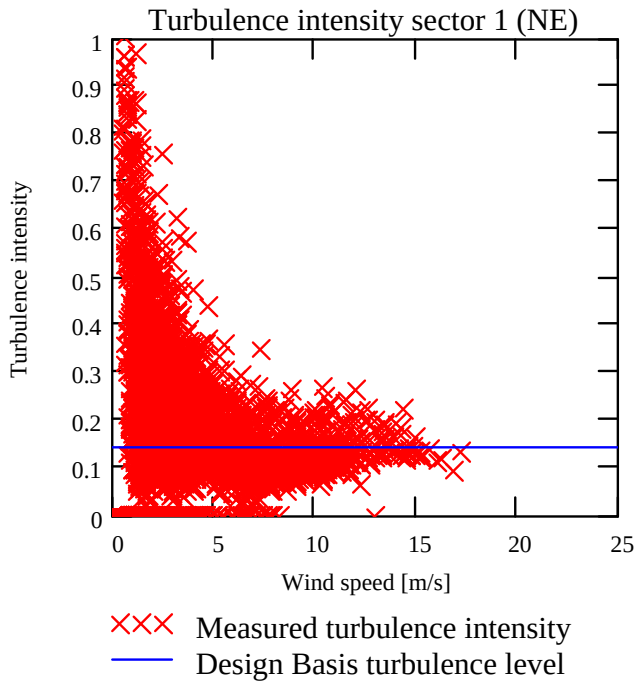
- Anemometertype
- Definisjon

$$I_u = \frac{\sigma_u}{U}$$

- Ingeniør modell

$$I_u(z) = \frac{1}{\ln\left(\frac{z}{z_0}\right)}$$

- Over land:
  z=50m, z_0=0.05
  => Iu=14%
- Over vann:
  z_0=0.01. Iu=11.7%



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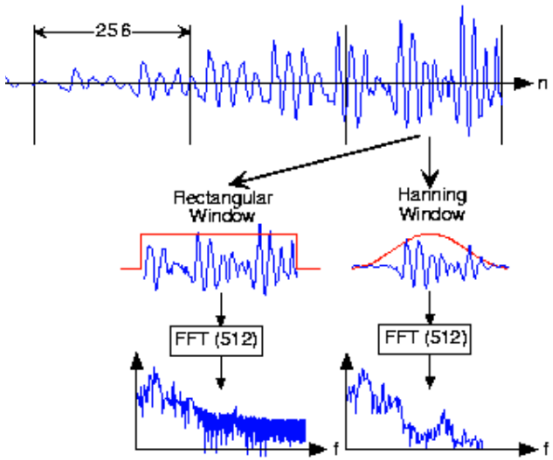
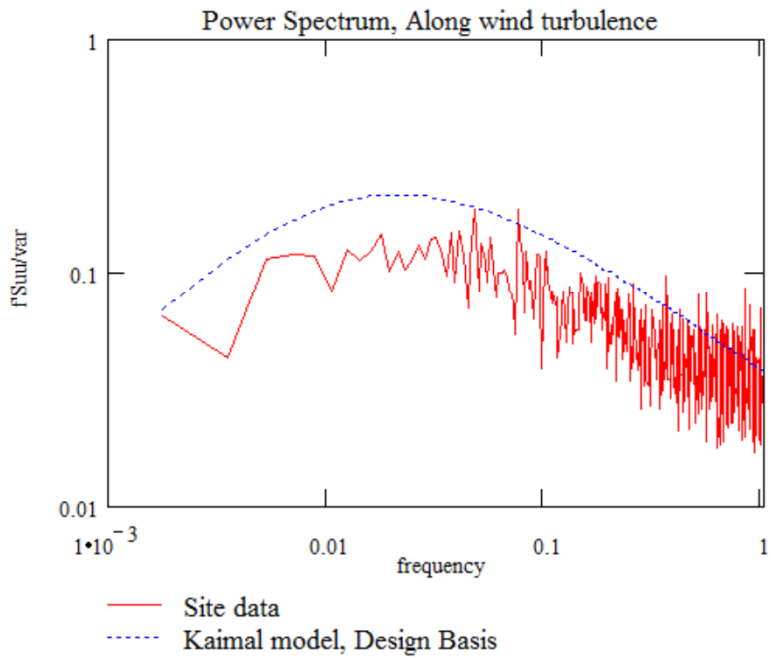
Resultater - vindspekter



- Spekter (Kaimal):

$$\frac{f \cdot S_i(f)}{\sigma_i^2} = \frac{\chi_i}{(1 + 1.5 \cdot \chi_i)^{5/3}}$$

$$\chi_i = \frac{L_i \cdot f}{v_{10}(z)} \qquad L_i = \lambda_i \cdot z$$



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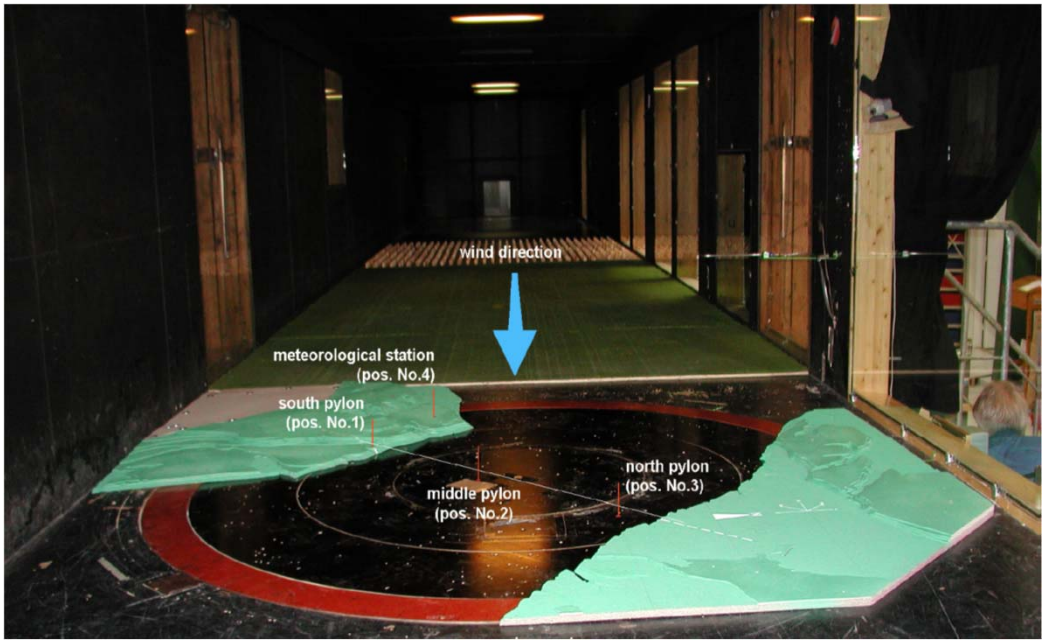
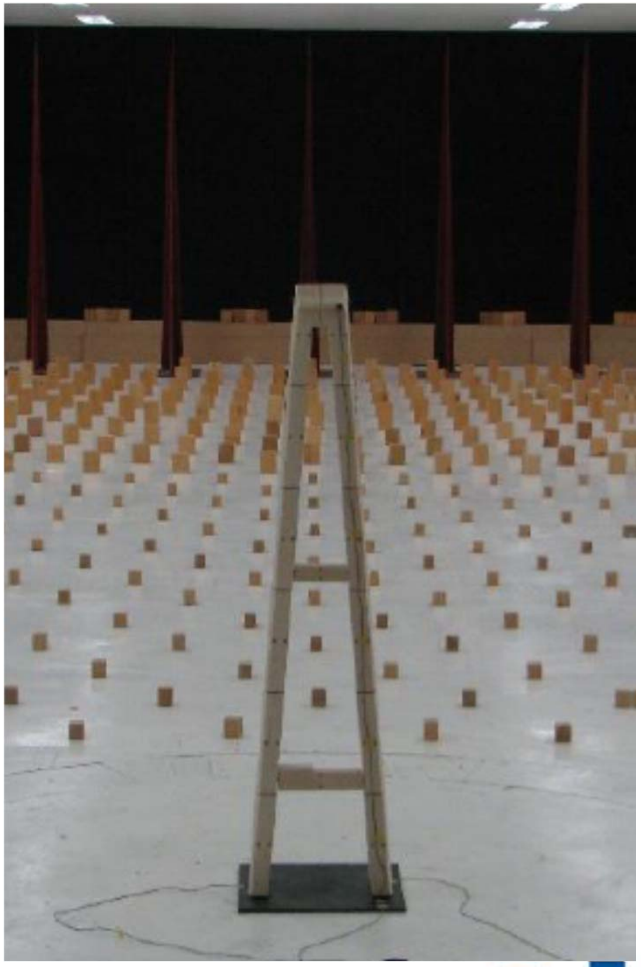
Oppsummering av vindklima

Description	Param.	Value
Return period permanent structure.	-	100 y
Return period during construction.	-	10 y
Wind speed conversion factor. 100y -> 10y	-	0.874
Terrain roughness and terrain factor normal to bridge axis	z_0, k_t	0.01 m, 0.17
Terrain roughness along bridge axis	z_0, k_t	0.05 m, 0.19
Density of air	ρ	1.25 kg/m^3
Basis wind speed, 100y	V_b	28.7 m/s
Mean wind speed 10-min avg., norm. to bridge axis at z=61m, 100y	V_{10}	42.5 m/s
Gust wind speed, normal to bridge axis at z=61m, 100y	V_g	59.6 m/s
Along wind turbulence intensity, u, normal to bridge at z=61m	I_u	11.5 %
Along wind turbulence intensity, u, along to bridge at z=61m	I_u	14.1 %
Cross wind horizontal, v	I_v	0.8*I_u
Cross wind horizontal, w	I_w	0.6*I_u
Length scale in wind spectrum, u-component (see below)	λ_u	12
Length scale in wind spectrum, v-component (see below)	λ_v	6
Length scale in wind spectrum, w-component (see below)	λ_w	2
Coherence decay parameter	C	10.0, 6.5, 3.0
Flutter instability limit for complete bridge (at z= 61 m)	V_{cr}	63.8 m/s
Flutter instability limit during construction (at z= 61 m)	$V_{cr\text{-}constr}$	55.8 m/s

Vindtunnelforsøk

- Terrengmodell
- Seksjonsmodell
- Tårn
- Full aeroelastisk





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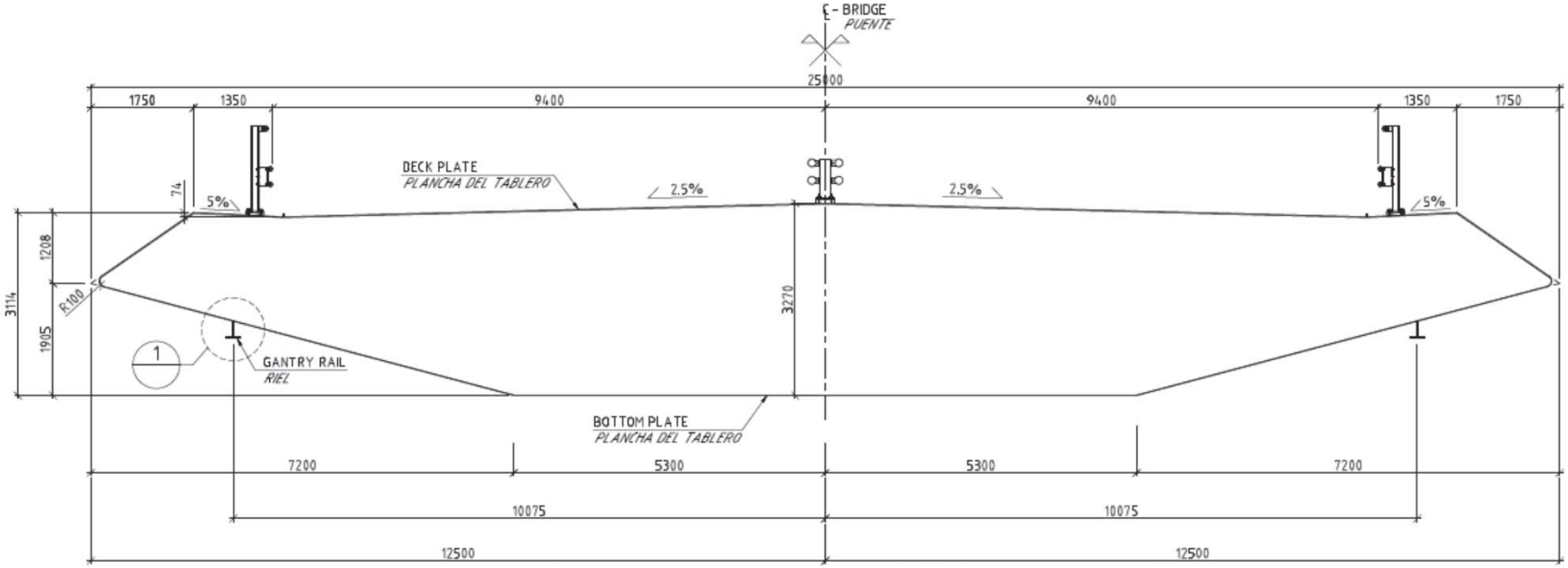
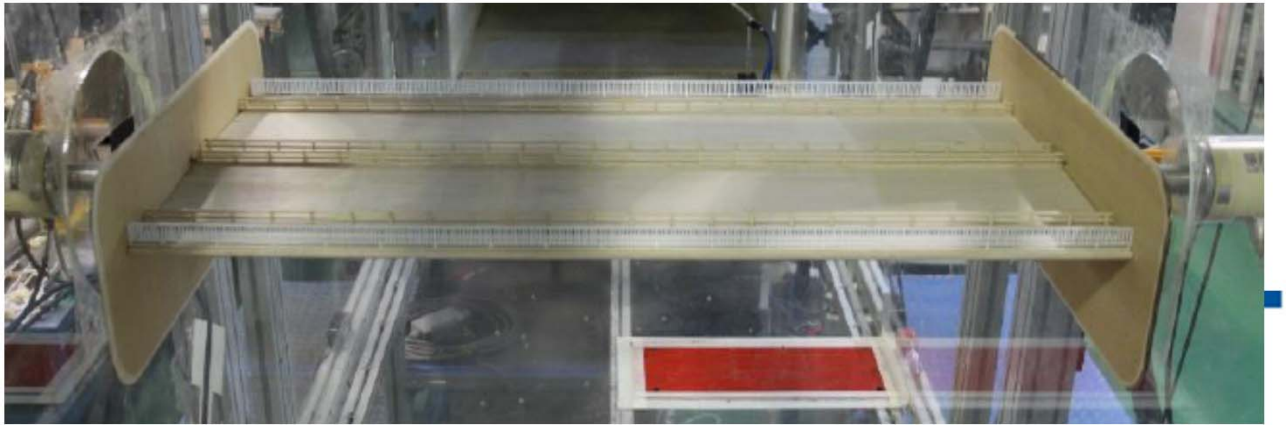
Seksjonsmodellforsøk





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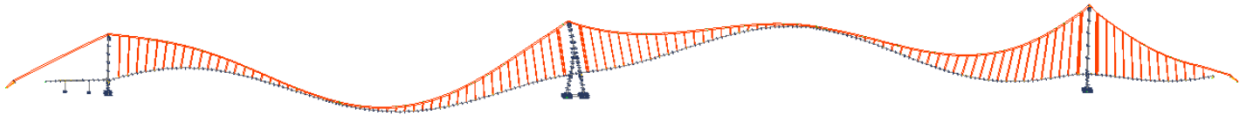
Flutter

First anti-metric vertical mode. f_{e3}=0.124

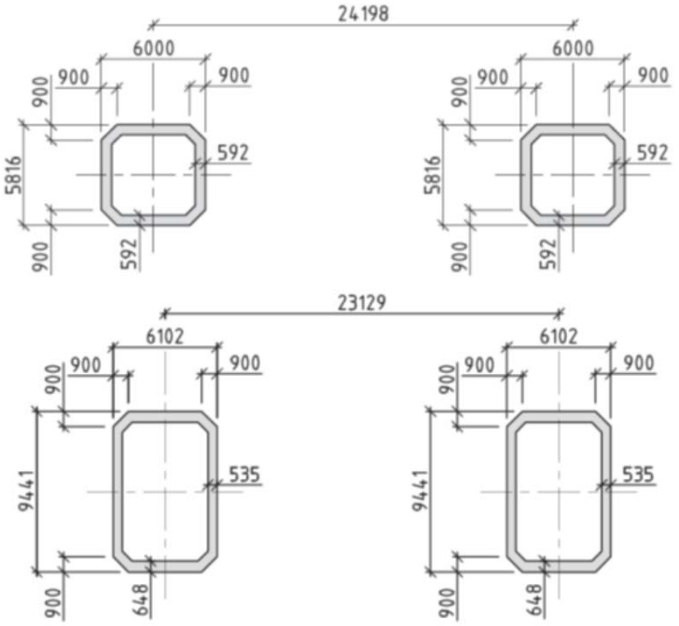


First symmetric vertical mode. f_{e5}=0.153 Hz:

First anti-metric vertical mode. f_{e29}=0.375 Hz:

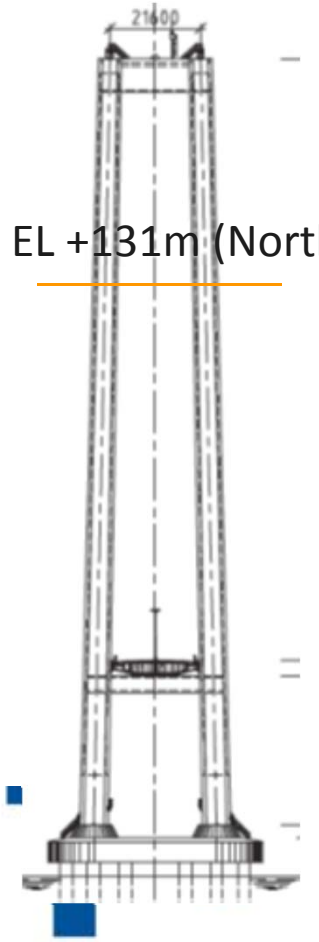
Tårn – seksjonsmodell

- Koeffisienter (0-90 deg)
- Glatt og turbulent strømning



Nord tårn

Syd tårn



EL +131m (North)

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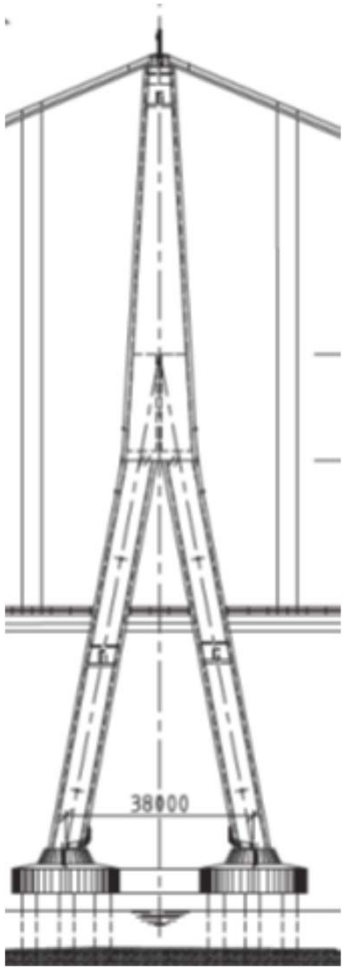
Aeroelastisk tårnmodell

- Aeroelastic tests
  - **Aeroelastisk respons**
    (frittstående og ferdig bru)
  - **Virvelavløsning**
  - **Kritisk vindhastighet for galloping.**
  - **Resultater:**
    - **Forskyvninger i tårntopp**
    - **Representative bøyemomenter**

Main frequencies for freestanding tower		
Mode	Central	North
1	0,414Hz	0,114Hz
2	0,797Hz	0,236Hz
3	1,253Hz	0,473Hz
4	1,376Hz	0,511Hz
5	1,521Hz	0,614Hz



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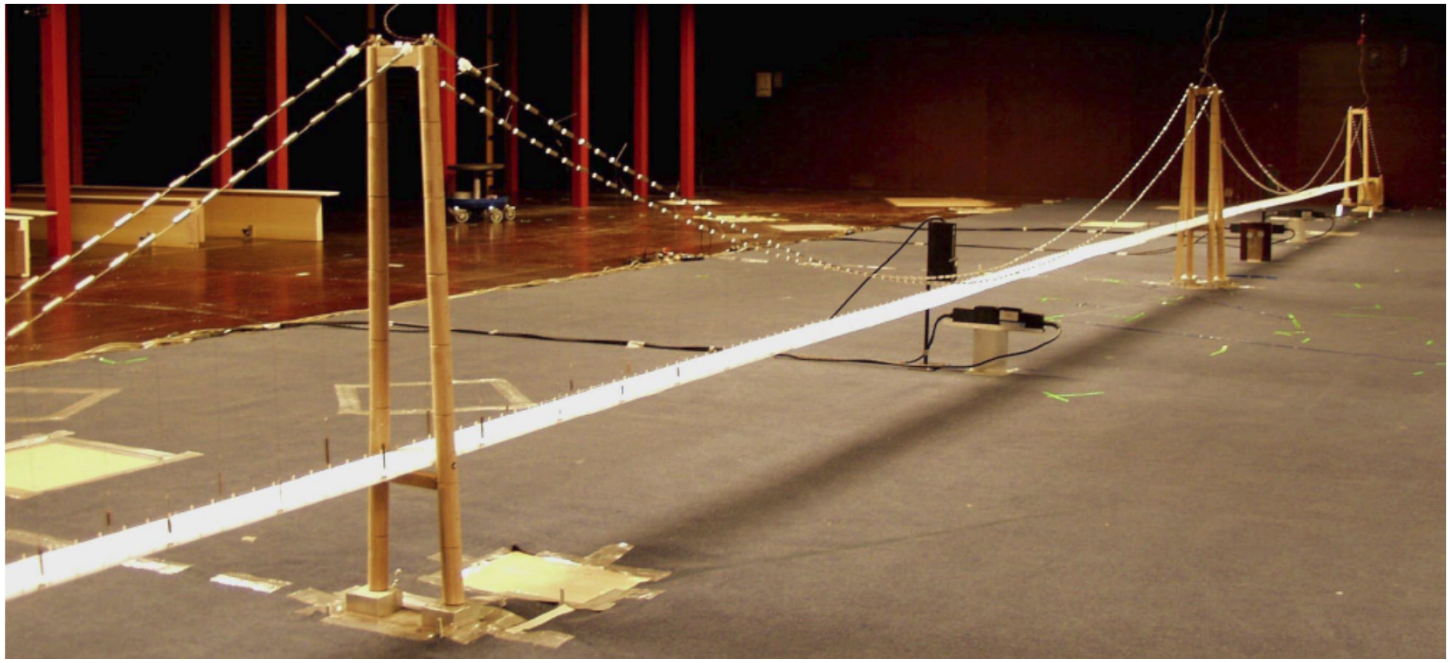
Aeroelastisk brumodell

- Skal utføres hvis andre forsøk tilsier det



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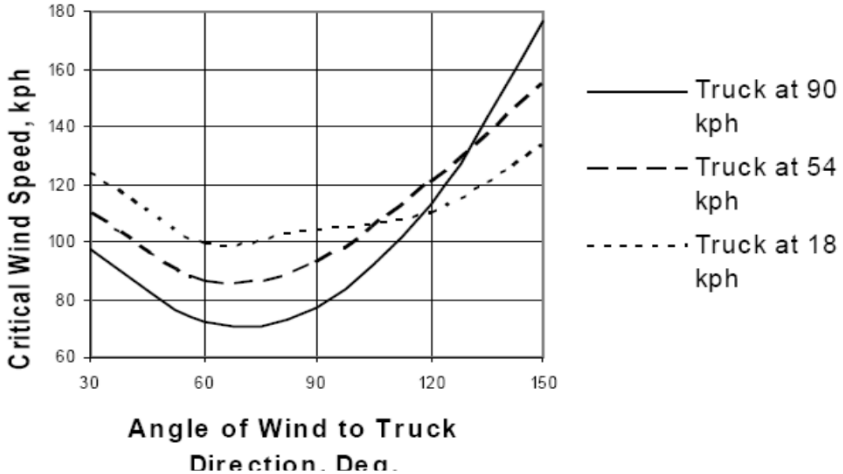
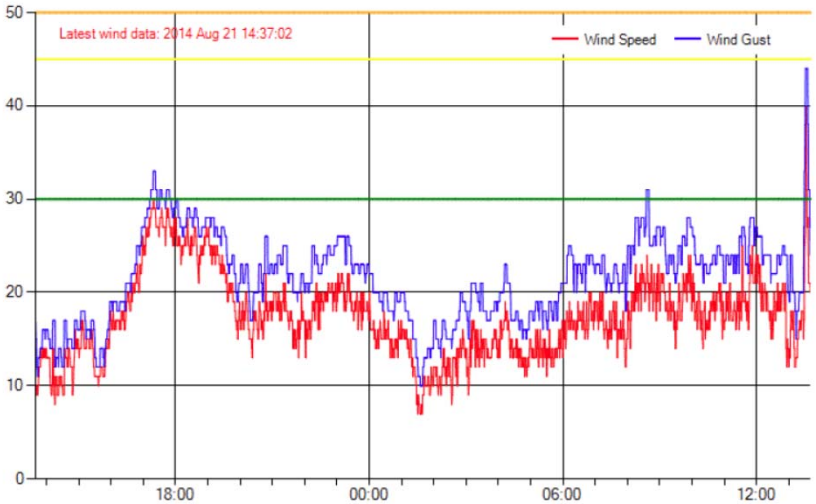
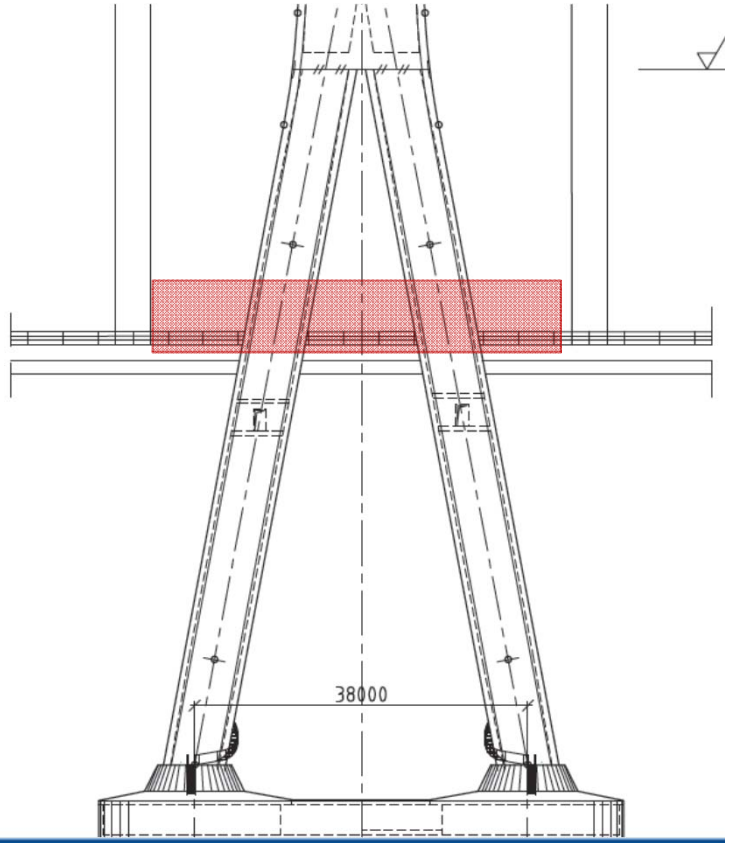
Spesielle problemstillinger - vind

- Plutselige endringer av vind på kjøretøy

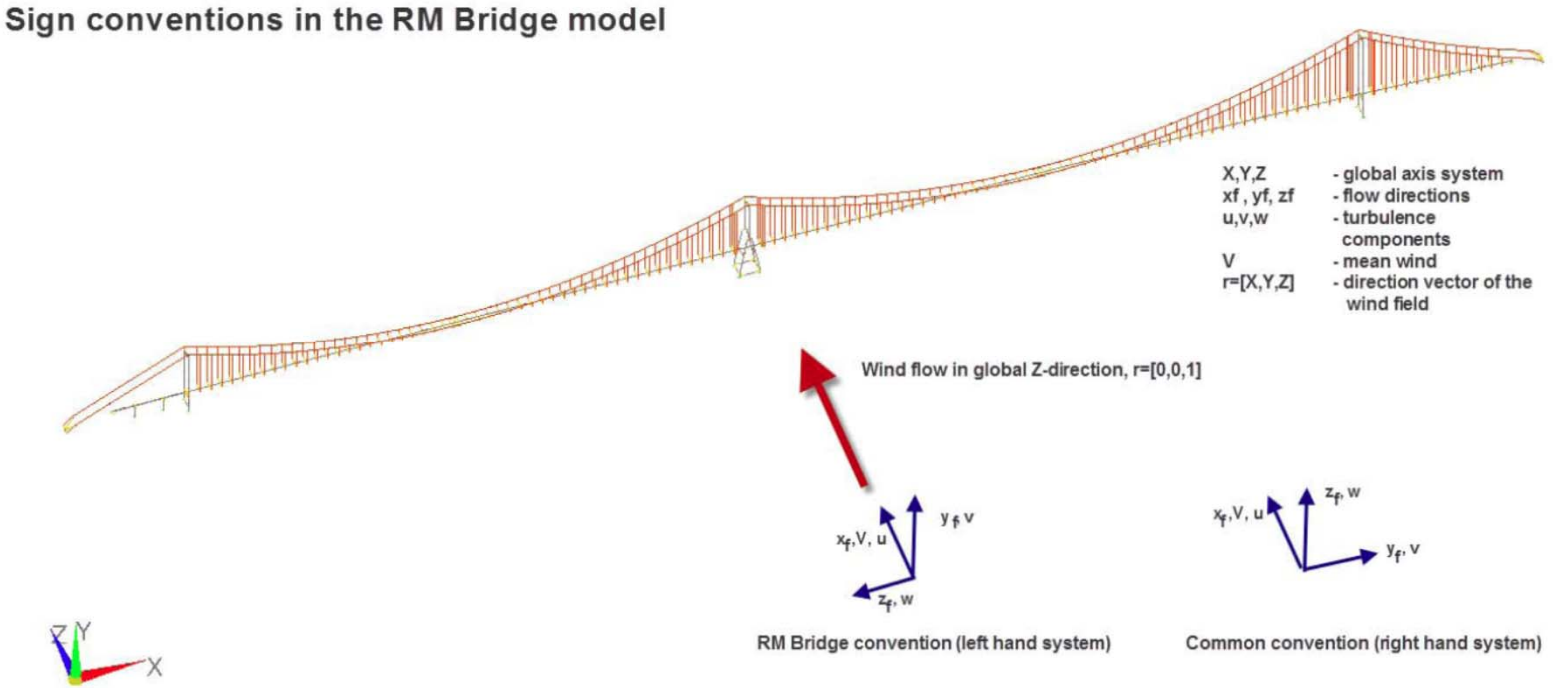






Beregninger – NB: foreløpige resultater!

- RM Spaceframe FEM modell
- Statiske og dynamiske vindmomenter
- Forskyving i brukasse
- Forskyvning i tårntopp



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Vind koeffisienter

Aero Classes (AC)		Typical dimensions		Static load coefficients					
Nb.	**Name**	**B** [m]	**D** [m]	**CD** [-]	**CL** [-]	**CM** [-]	**CD'** [1/deg]	**CL'** [1/deg]	**CM'** [1/deg]
10	Cables		0.557	0.820	-	-	-	-	-
20	Hangers		0.100 (0.080)	0.800	-	-	-	-	-
100	Girder approach south*								
110	Stiffening girder main spans	25.000	3.270	0.822	-0.195	0.030	0.002	0.0775	-0.017

* To be implemented in detailed design

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Resultater – Brukasse - Moment om svak akse.

- Vindlast. 41MNm (ufakt) x 1.4 = 57MNm
- Totallast: 216MNm

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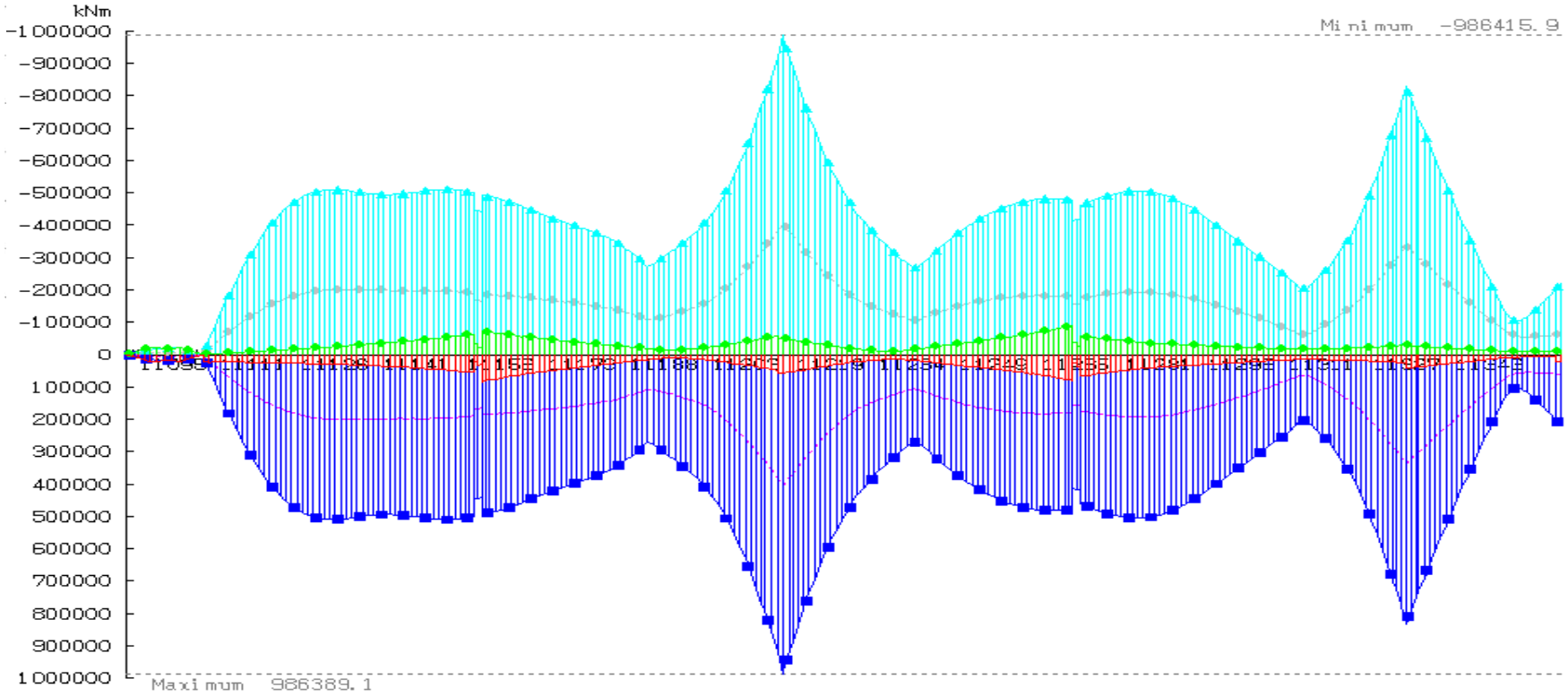
Resultater – Brukasse - Moment om sterk akse.



- Vindlast. 670MNm (ufakt) x 1.4 = 940MNm
- Totallast: 980MNm

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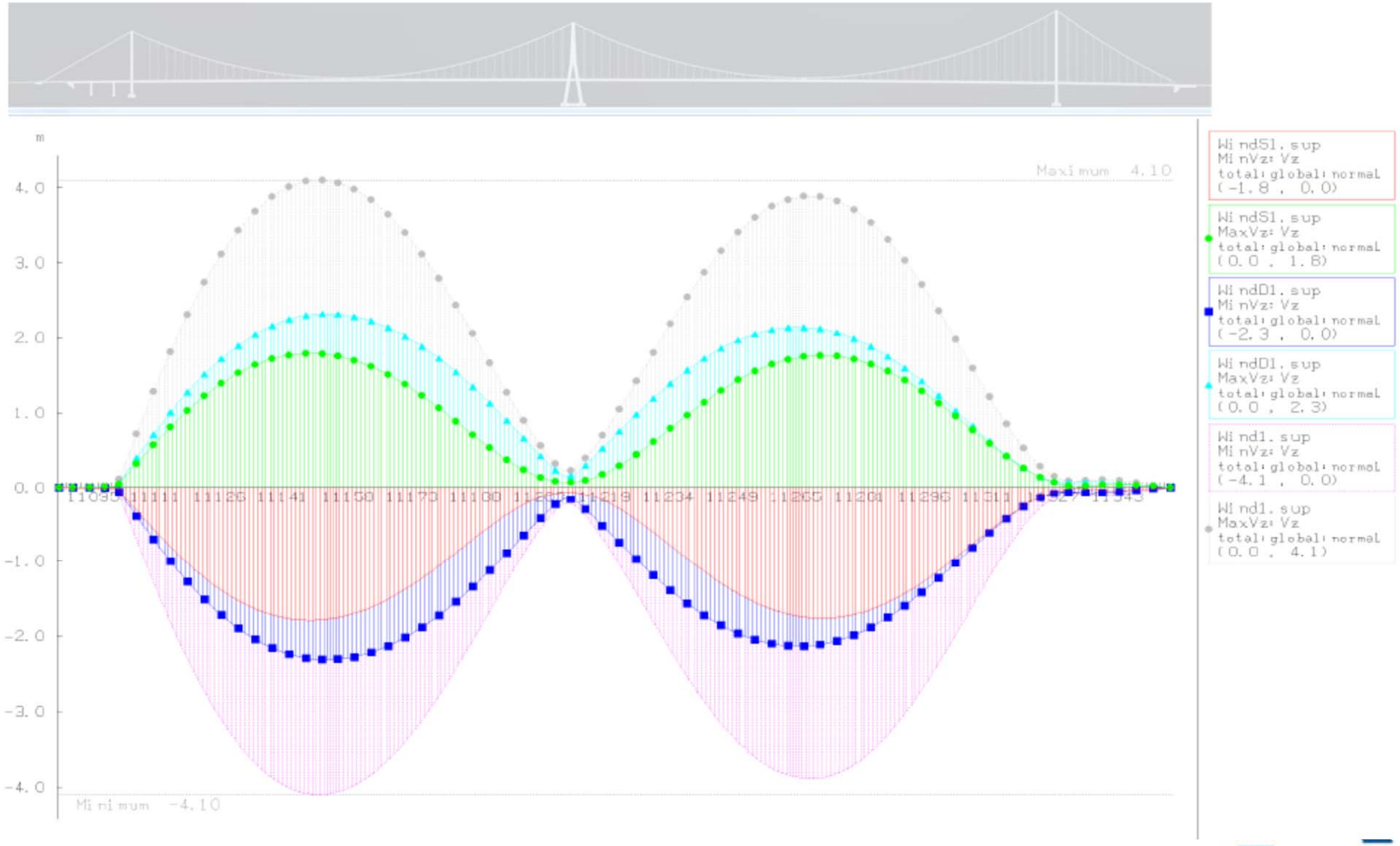
Brukasse – Horisontalforskyvning - vind.



- Horisontalforskyvning, vind: +/- 4m
- Sentraltårn 300mm / 90mm
- Nordtårn: 800mm / 100mm

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Videre framdrift

- Tolke måledata fra brustedet (fra november)
- Vindtunnellforsøk (fra oktober)
- Beregninger
- Dimensjonering

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