# Dynamic analyses of tankers moored at berth

Marin byggteknikkdagen 18.4.2018

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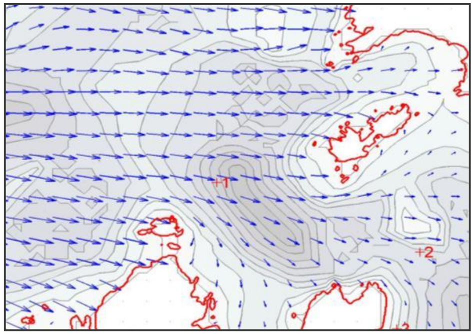
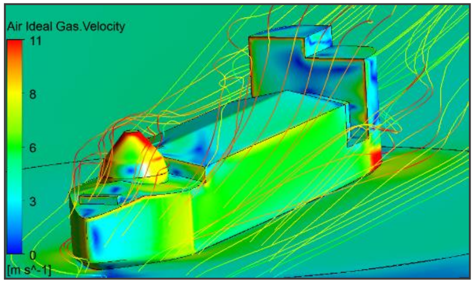
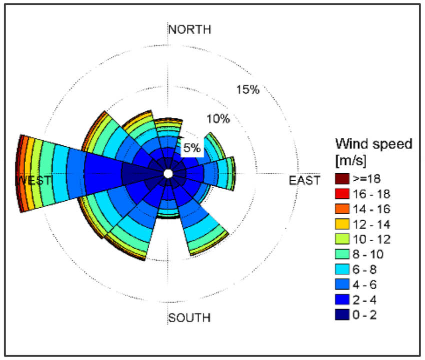
# Department of Marine Tecnology, Tromsø

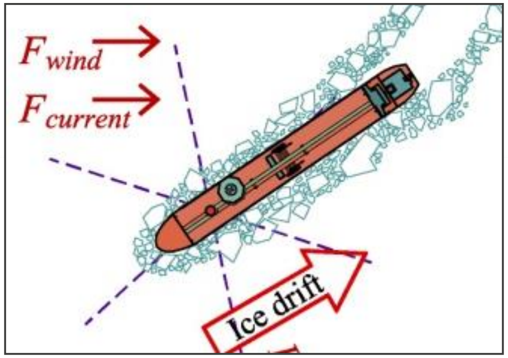
- 27 marine & coastal engineers
- 3 sub-departments:

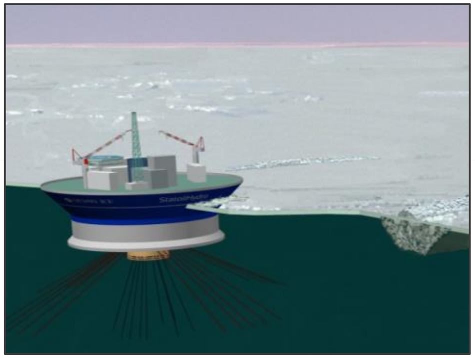
  1. Marine environment and aquaculture
     Metocean, CFD analyses, aquaculture services
  2. Marine technology
     Hydrodynamic analyses, sea ice analyses
  3. Coastal structure and harbour facilities
     Harbour planning, port and jetty engineeringdesign





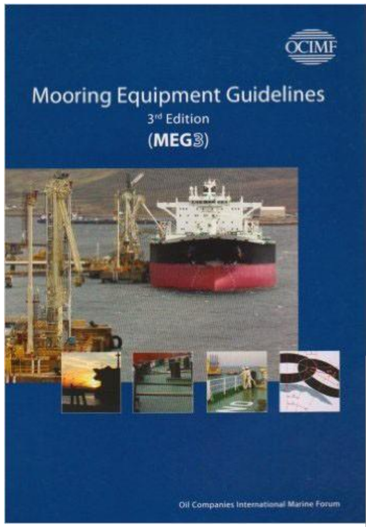



# Dynamic analyses of tankers moored at berth

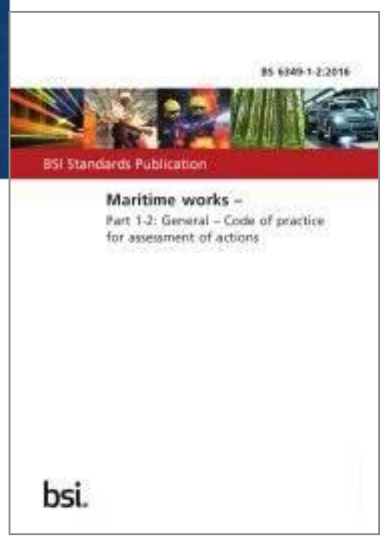
- Case study Kårstø jetty no. 3
- Analysis methodology
- Metocean design basis
- Harbour planning

# Kårstø mooring analyses

# Guidelines

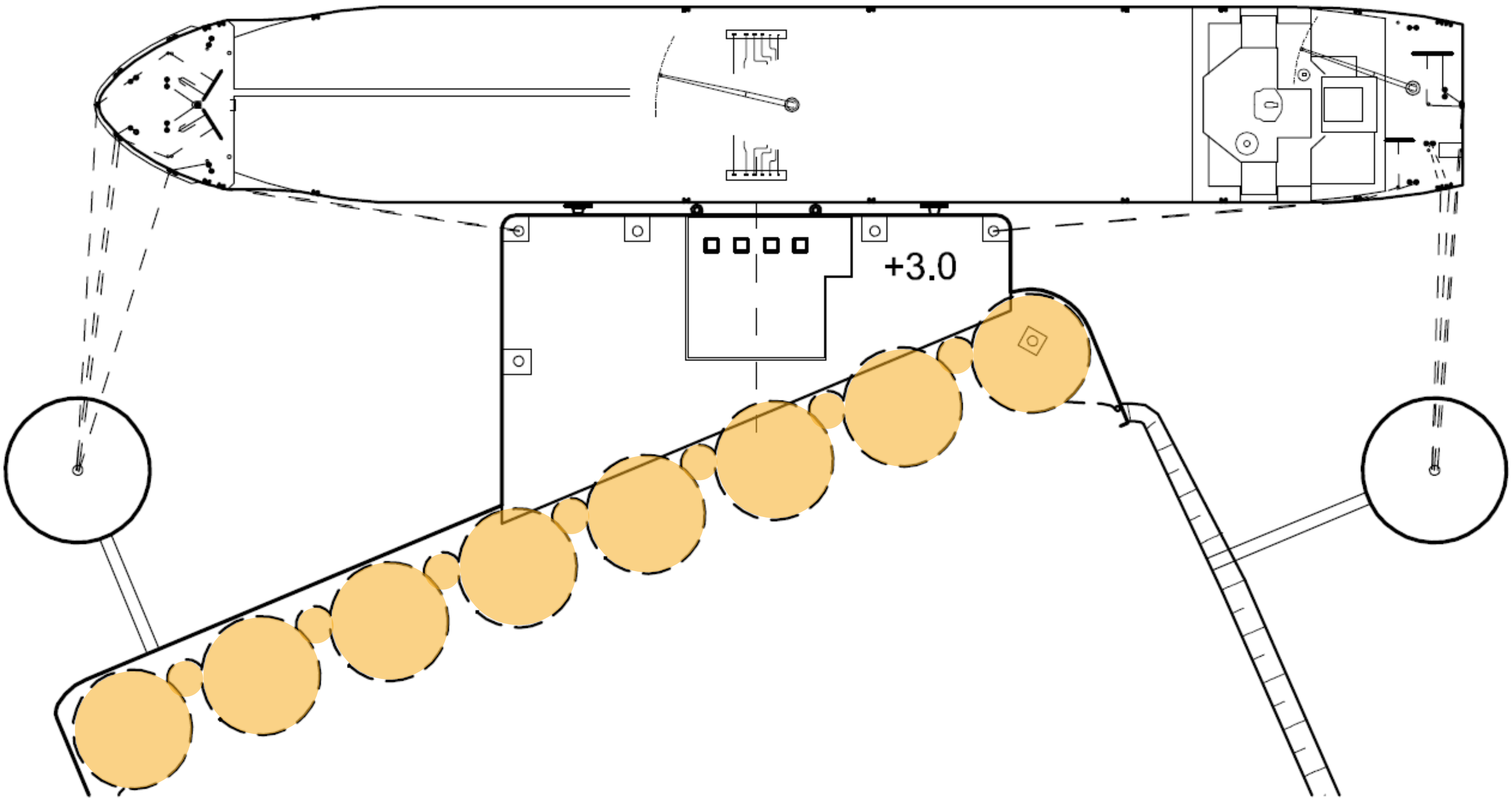



OCIMF (Oil Companies International Marine Forum)
Mooring Equipment Guidelines 3rd Edition

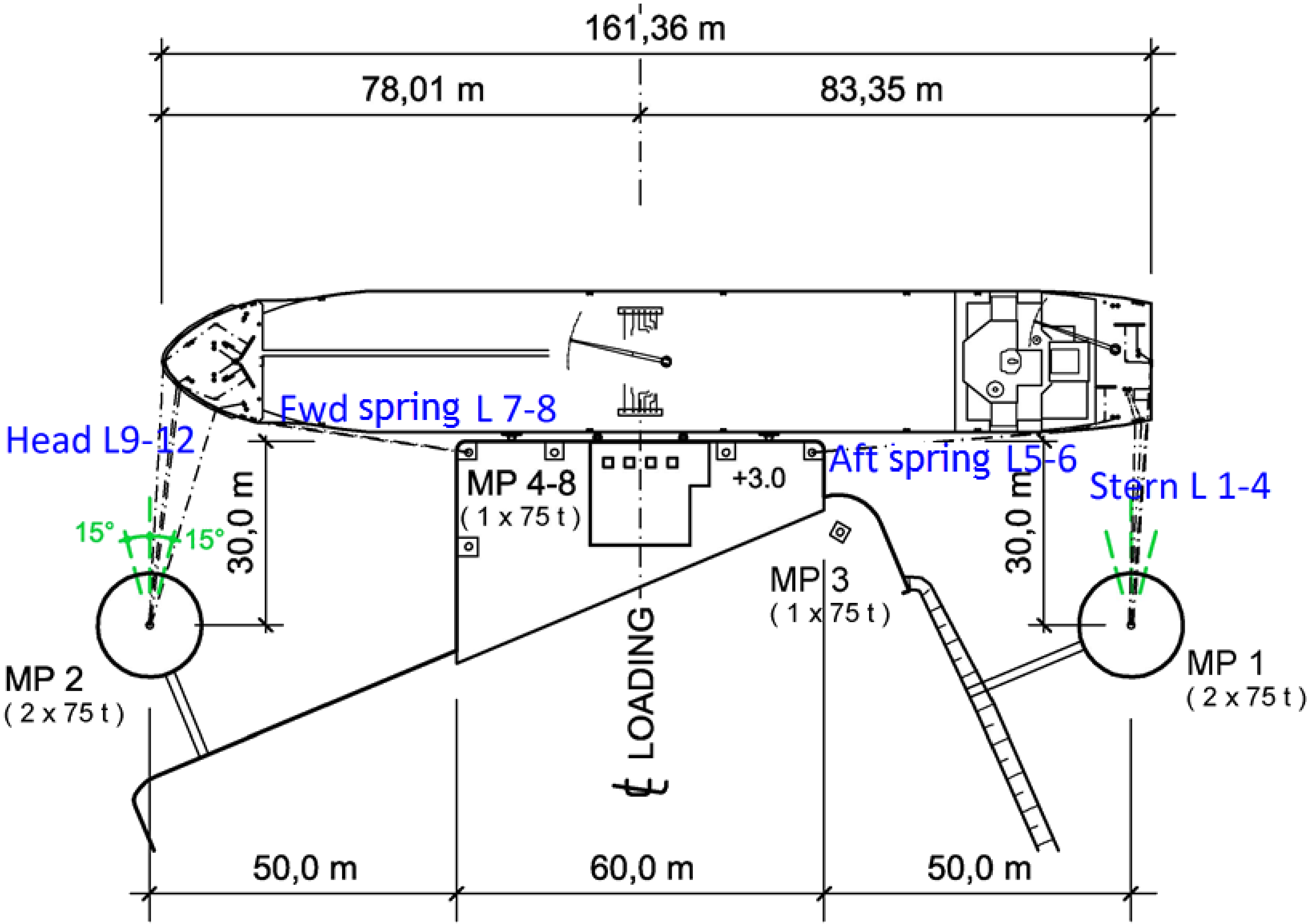



British Standards Institution
BS6349 Maritime Works

# Jetty 3 and old jetty front



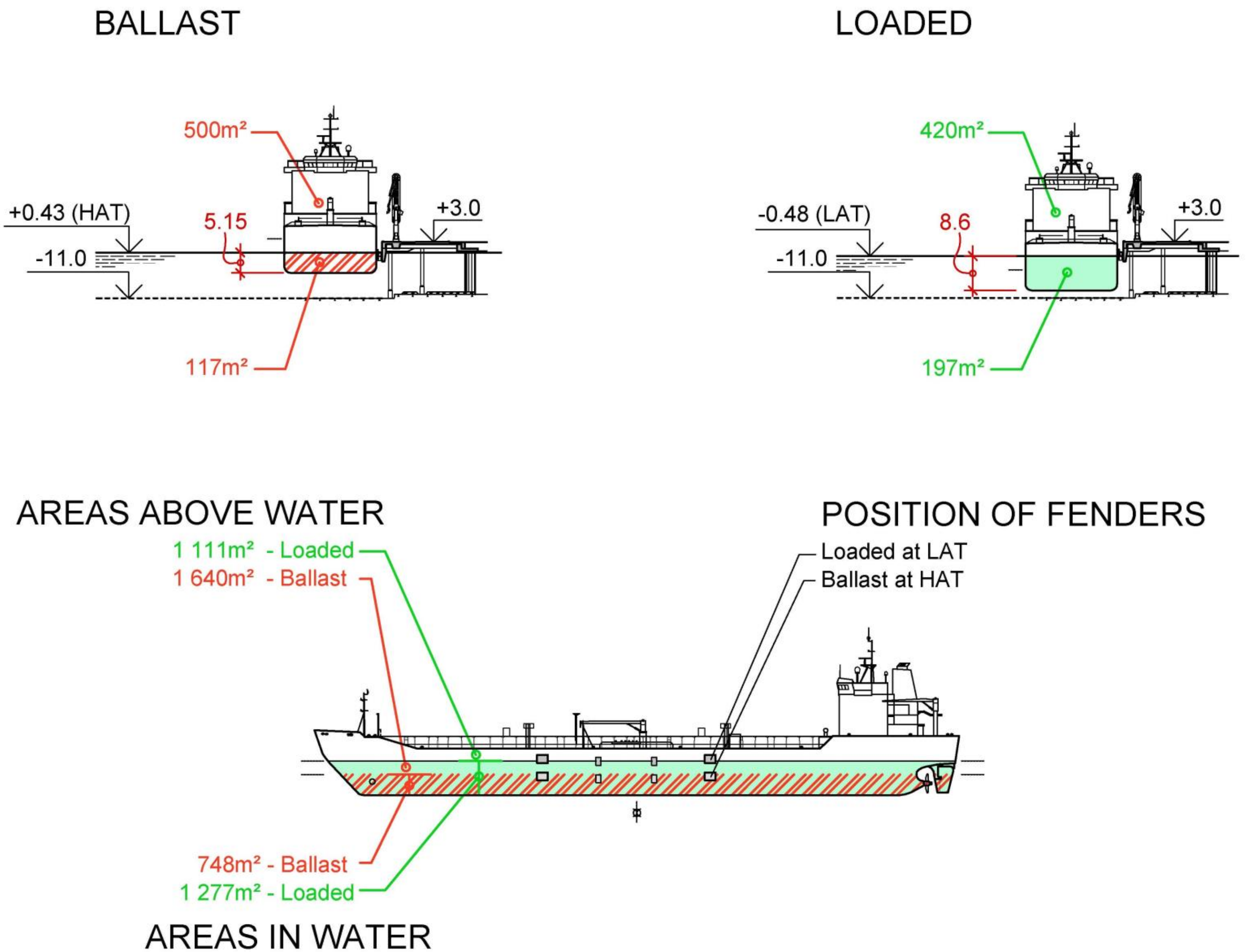
# Jetty 3 - Mooring layout



# ISARSTERN – 17 080 DWT tanker


| | Isarstern |
|---|---|
| Summer Dead weight tonnage (DWT) | 17 080 t |
| Displacement (ballast/loaded) | 14 572 t / 25 631 t |
| Length over all (LOA) | 161.36 m |
| Extreme breadth | 23.00 m |
| Moulded depth | 11.70 m |
| Summer draft | 8.60 m |
| Draft (ballast/loaded) | 5.15 m / 8.60 m |

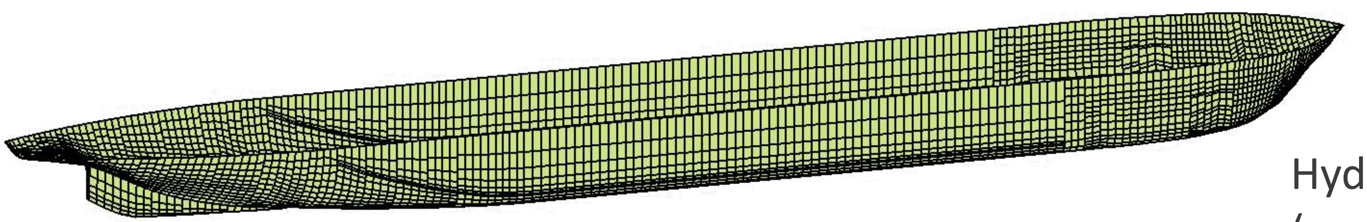
# Moored 17 080 DWT tanker



# Hydrodynamic model of Isarstern

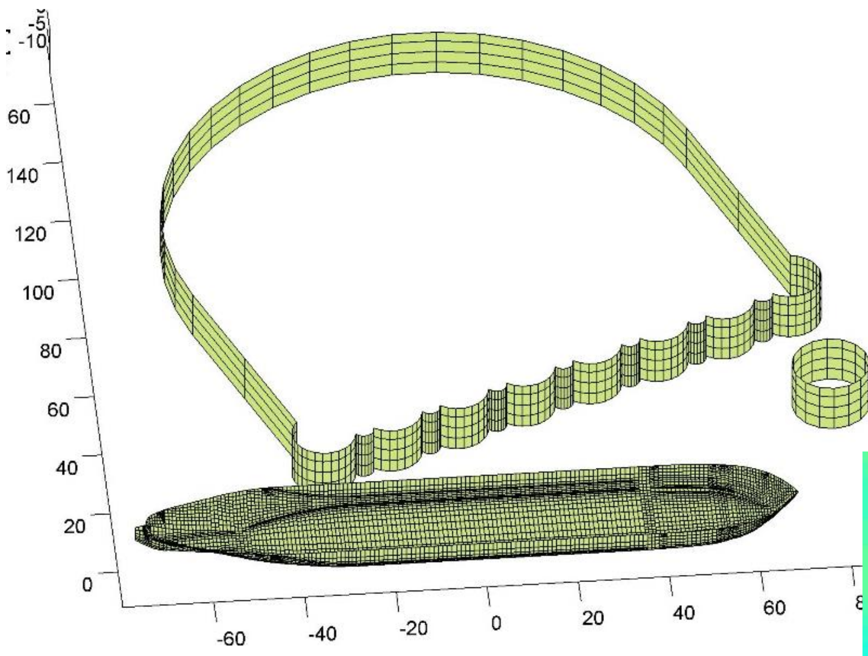
- Based on GA from the chemical tanker Isarstern
- Approximated 3D model

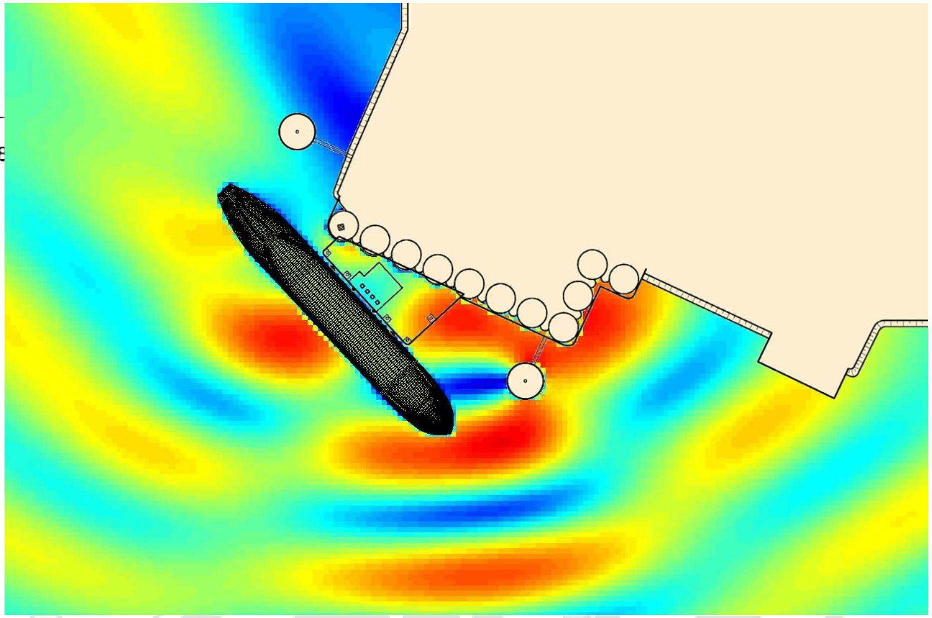
| | Isarstern (in calculation) |
|---|---|
| LOA | 161.36 m |
| Breadth | 23.00 m |
| Draft | 5.15 m / 8.60 m |
| Displacement | 14 572 t / 25 631 t |

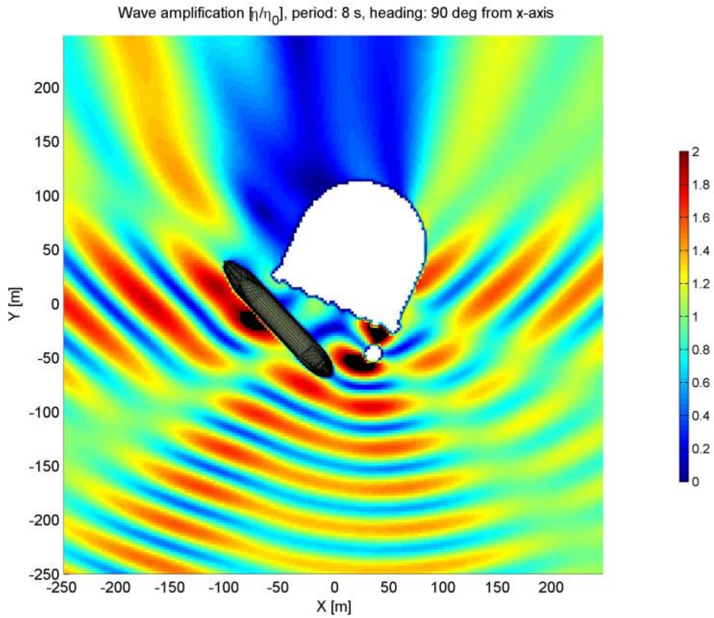


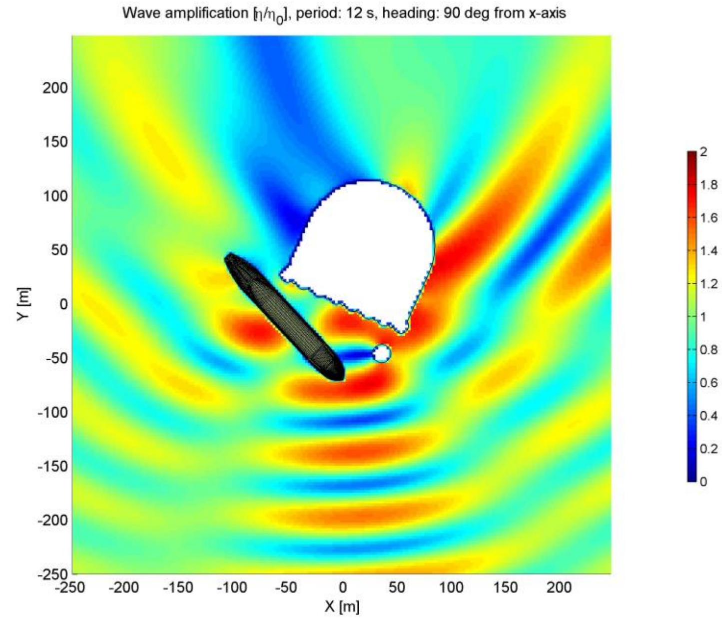
Hydrodynamic model (underwater hull)

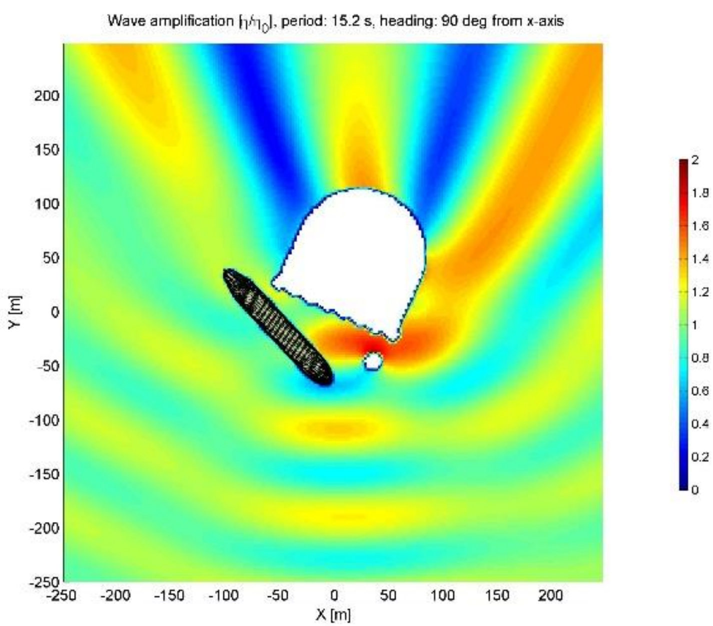
# Wave reflection on old quay front

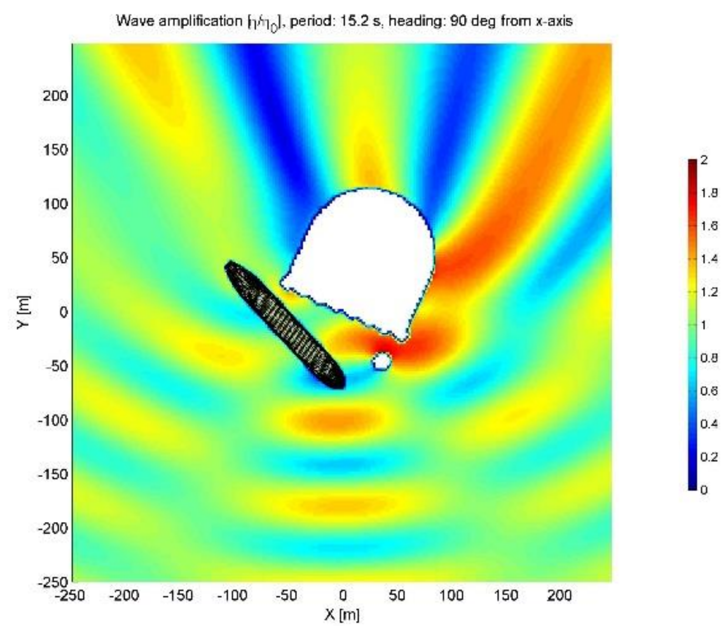


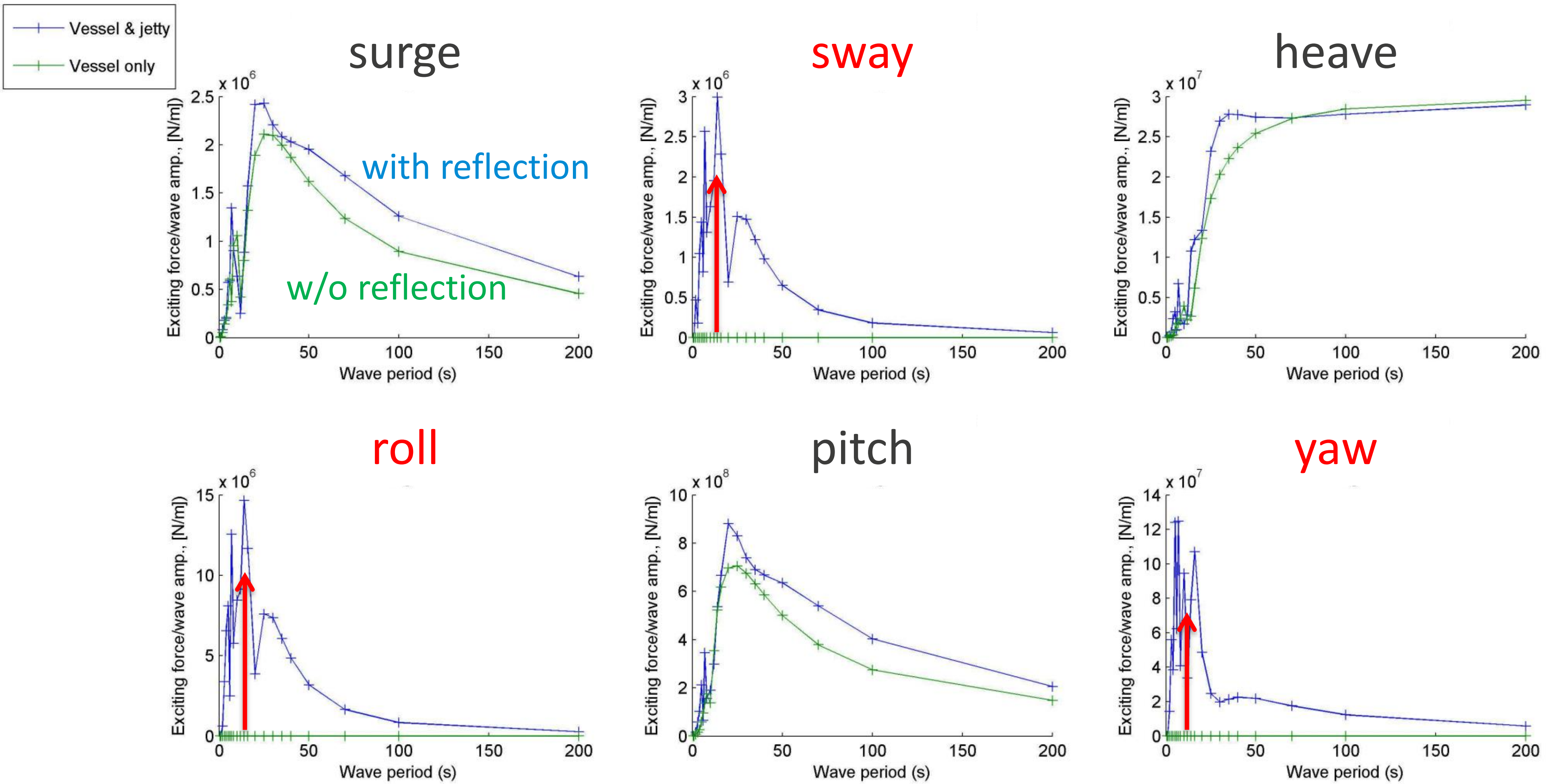

Wave amplification [$\eta/\eta_0$], period: 8 s, heading: 90 deg from x-axis
Y [m]
X [m]


Wave amplification [$\eta/\eta_0$], period: 12 s, heading: 90 deg from x-axis
Y [m]
X [m]

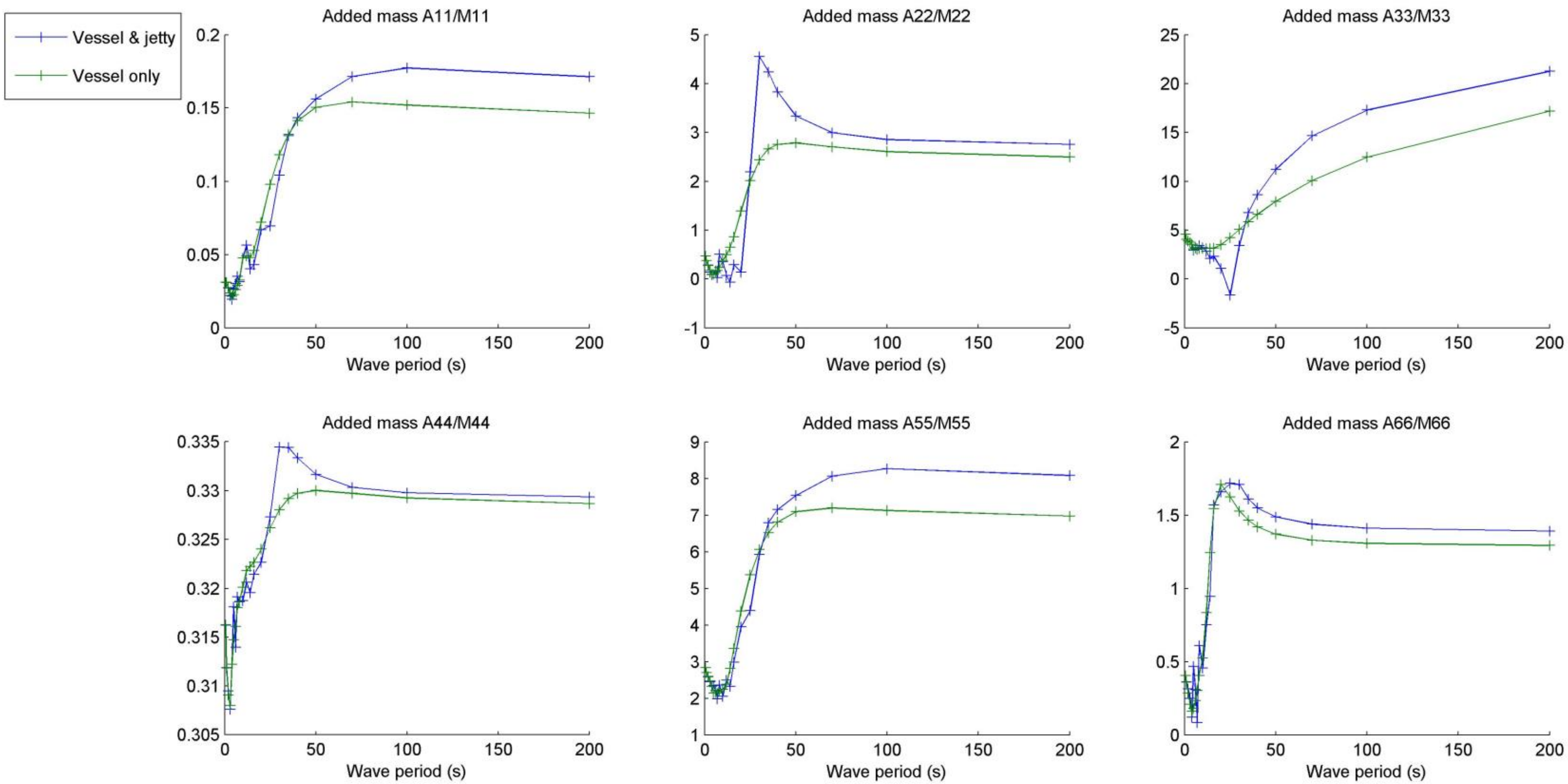

Wave amplification [$\eta/\eta_0$], period: 15.2 s, heading: 90 deg from x-axis
Y [m]
X [m]


Wave amplification [$\eta/\eta_0$], period: 15.2 s, heading: 90 deg from x-axis
Y [m]
X [m]

# Wave loads – effect of reflection – 0° heading

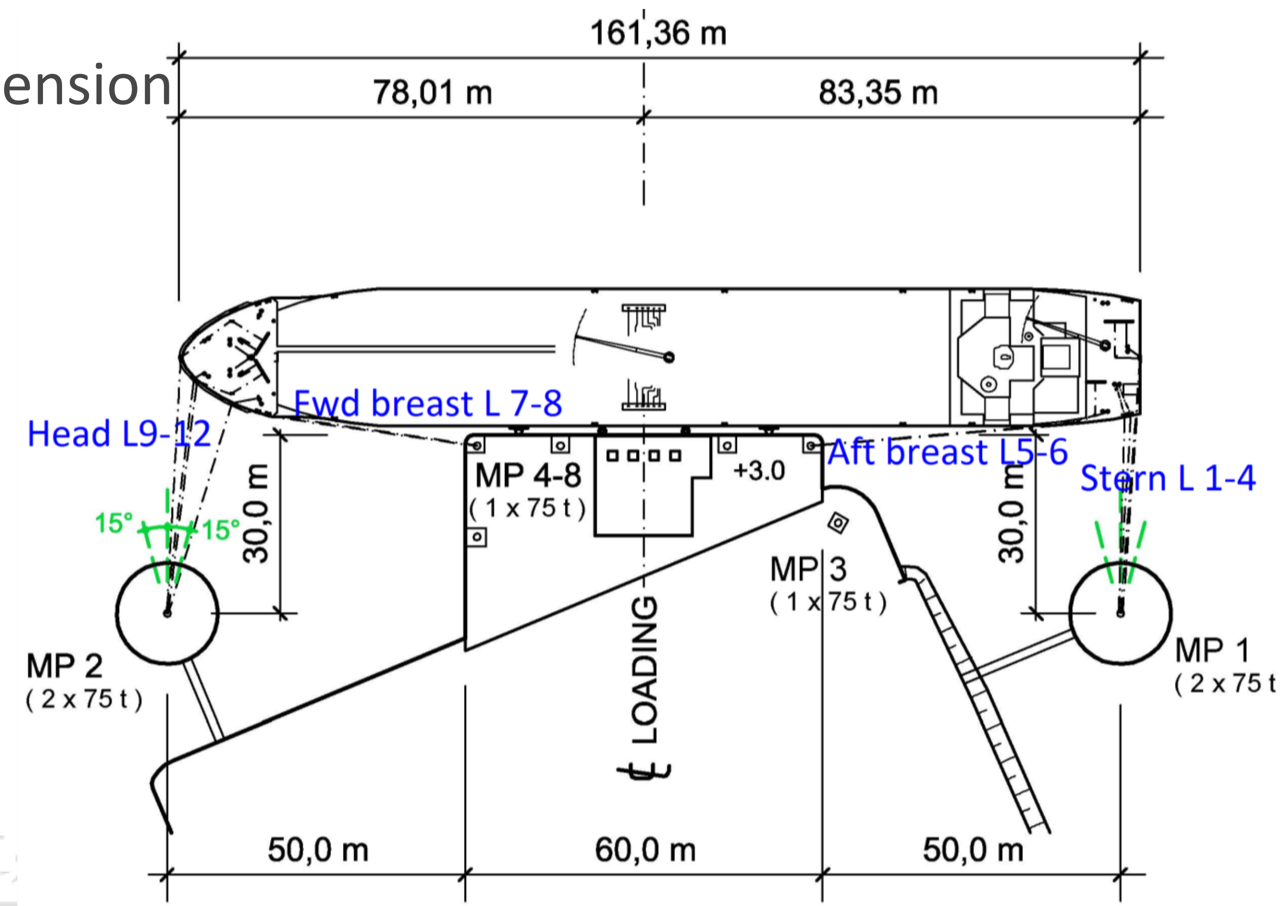


# Added mass (frekvensavhengig)



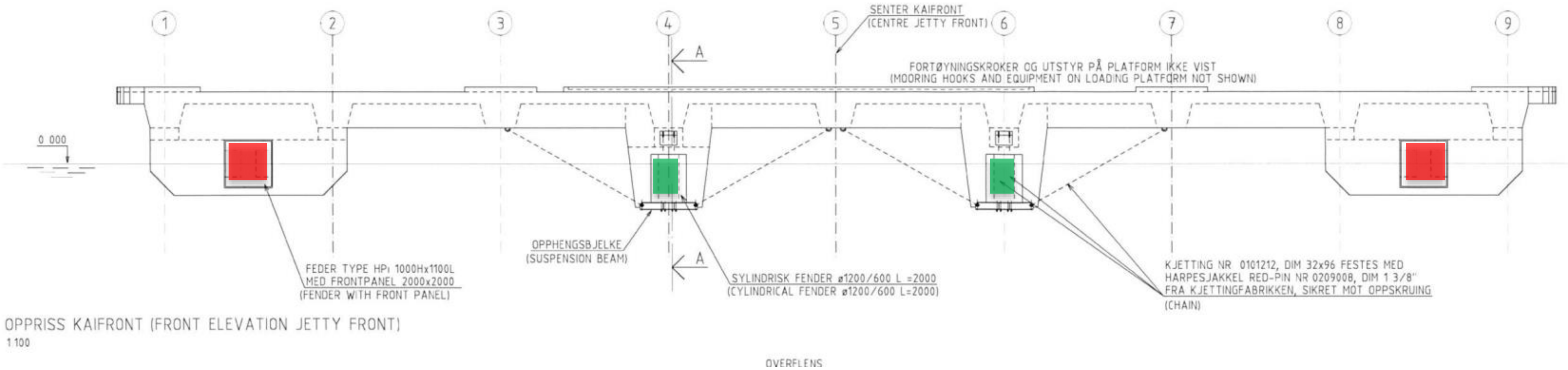
# Mooring lines

- Mooring line:
  - 60 mm Mixed Polyester and Polypropylene, 71 t MBL, SF: 2.00 (35.5 t SWL)
- Assumed 10 t pretension



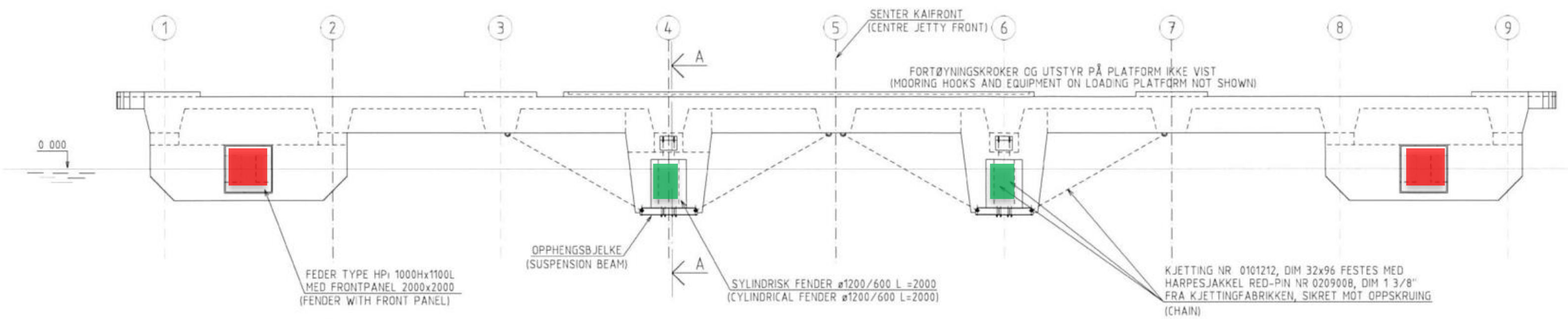
# Fenders

- Fenders
  - 2 outer cone cell fenders
  - 2 middle cylindrical fenders




# Fenders

- Fenders
  - 2 outer cone cell fenders
  - 2 middle cylindrical fenders




OPPRISS KAIFRONT (FRONT ELEVATION JETTY FRONT)
1:100

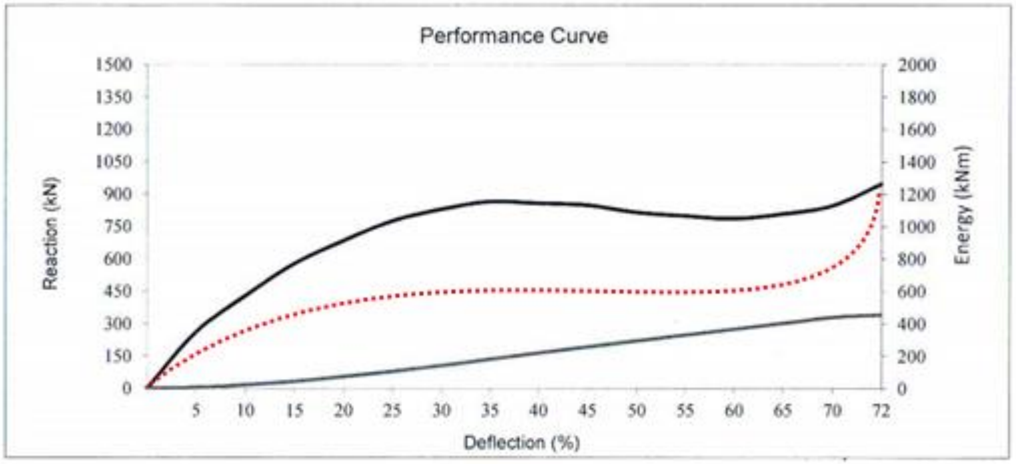



*Fig. 4-3 Characteristics of the Trelleborg cell fender SCN900E2.7 (type 1)*

# Environment - Wind

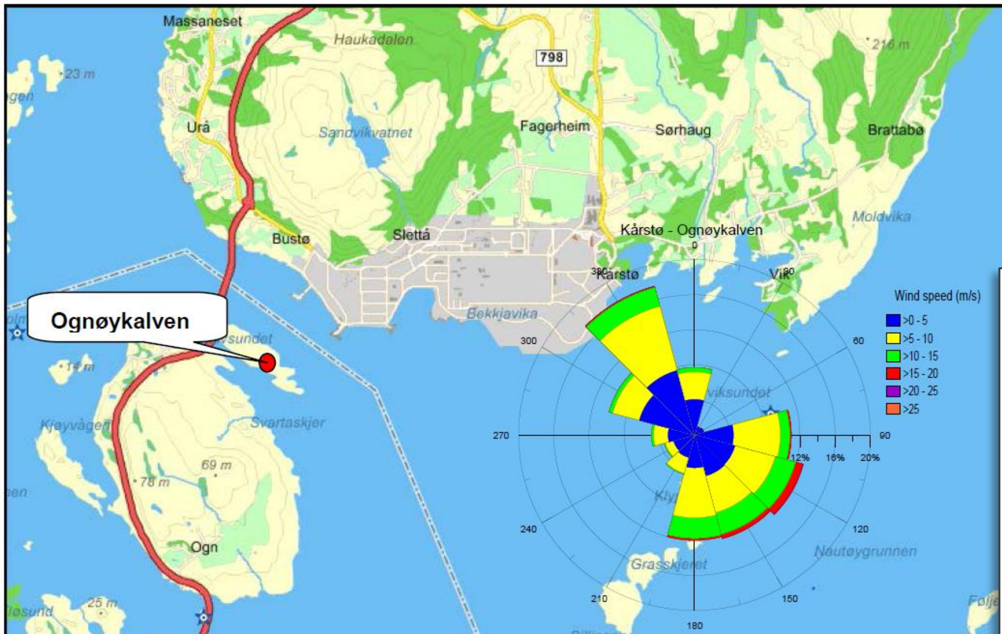
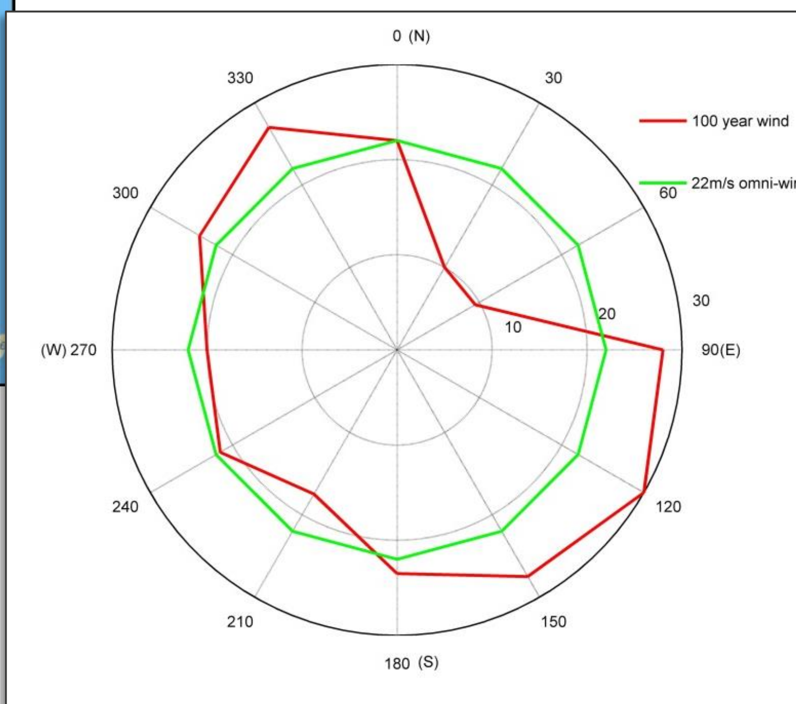



Figure 2.1 Wind rose at Kårstø (Ognøykalven) for the period 2009 - 2014.



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# Environment – Waves & swell

- Wind waves

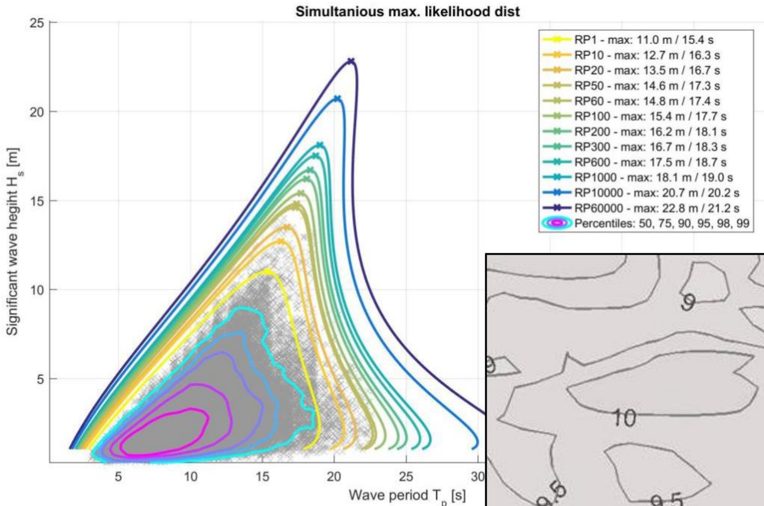
| Direction | 0º | 30º | 60º | 90º | 120º | 150º | 180º | 210º | 240º | 270º | 300º | 330º |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Return period 100yr | | | | | | | | | | | |
| Hs [m] | 0.4 | 0.4 | 0.4 | 1.2 | 1.5 | 1.6 | 1.7 | 0.9 | 0.4 | 0.5 | 0.6 | 0.5 |
| Tp [s] | 1.7 | 2.3 | 2.4 | 3.2 | 3.6 | 3.8 | 4.3 | 3.2 | 1.7 | 2.0 | 2.1 | 1.8 |

- Swell (RP100)

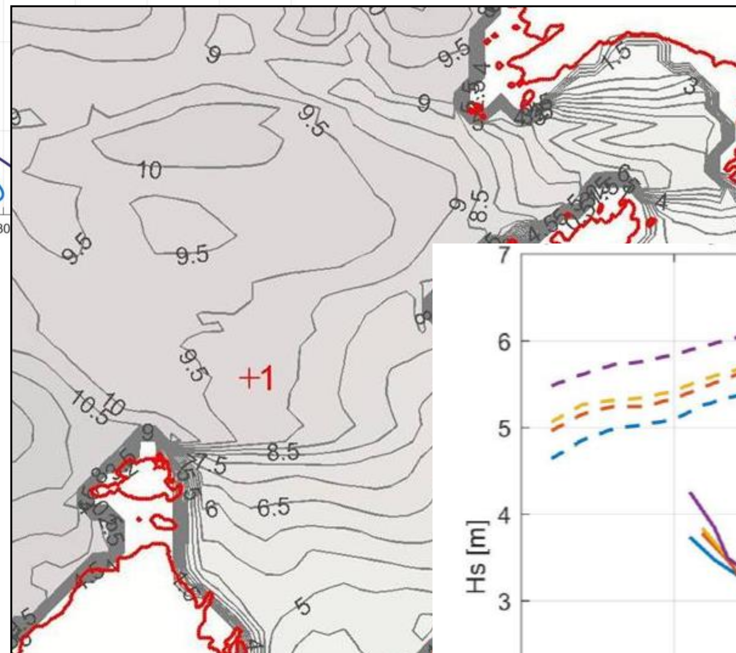
| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Hs [m] | NA | | | | | | 0.2 | 0.3 | 0.3 | 0.2 | NA | |
| Tp [s] | | | | | | | 13 | 14.1 | 15.4 | 16.4 | | |

  – Direction of swell at site assumed to be 180 deg.

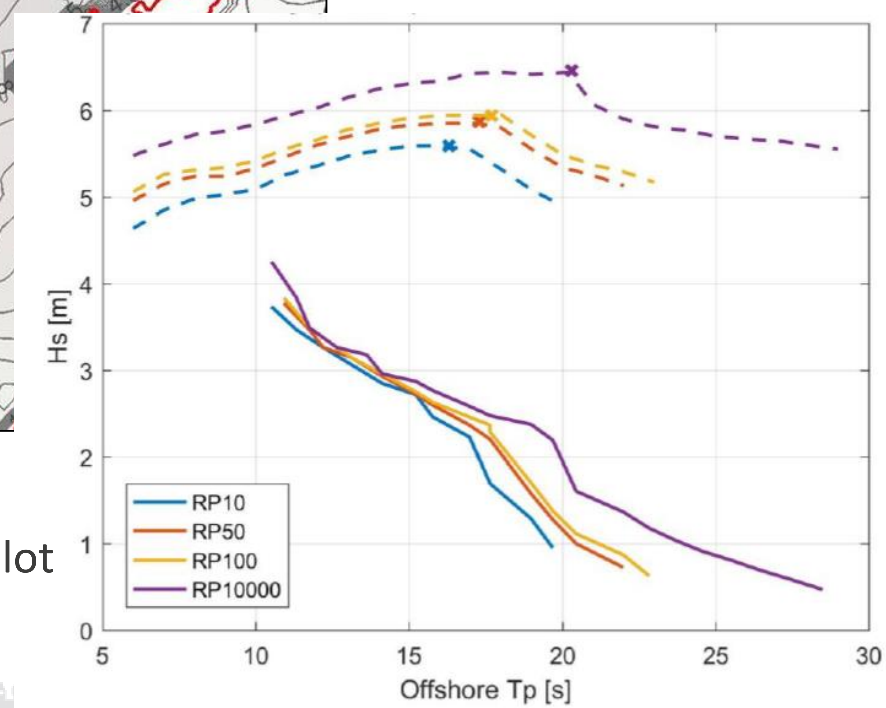
# Swell




Hindcast – historical wave data

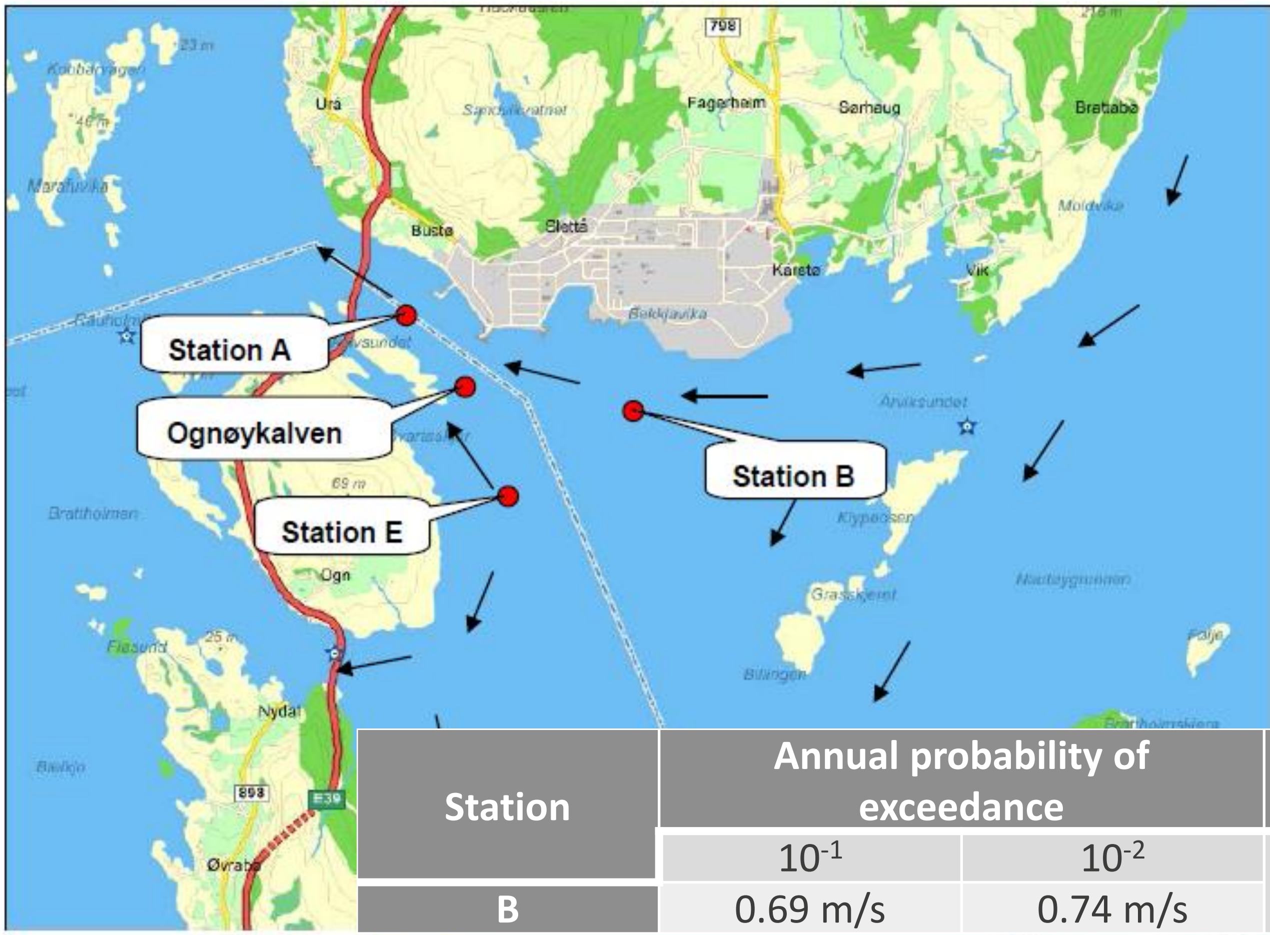



Wave propagation analysis




Hs-Tp Contour plot

# Environment - Current




| Station | Annual probability of exceedance | | Direction |
|---|---|---|---|
| | $10^{-1}$ | $10^{-2}$ | |
| B | 0.69 m/s | 0.74 m/s | 105/285 deg |

Figure 3.3 Current measurement positions and main residual currents at Kårstø.

# Environment - combination

- NORSOK recommendations

| Condition | Wind state | Wind wave state (from wind direction) | Swell | Current |
|---|---|---|---|---|
| **Extreme** | RP 100y | RP 100y | RP100 swell, Tp= 8s-17s | RP 10y |
| **Omnidirectional** | 22.0 m/s | Calculated wind wave | From 0 to 0.3 m | RP 100y |

# Simulation matrix

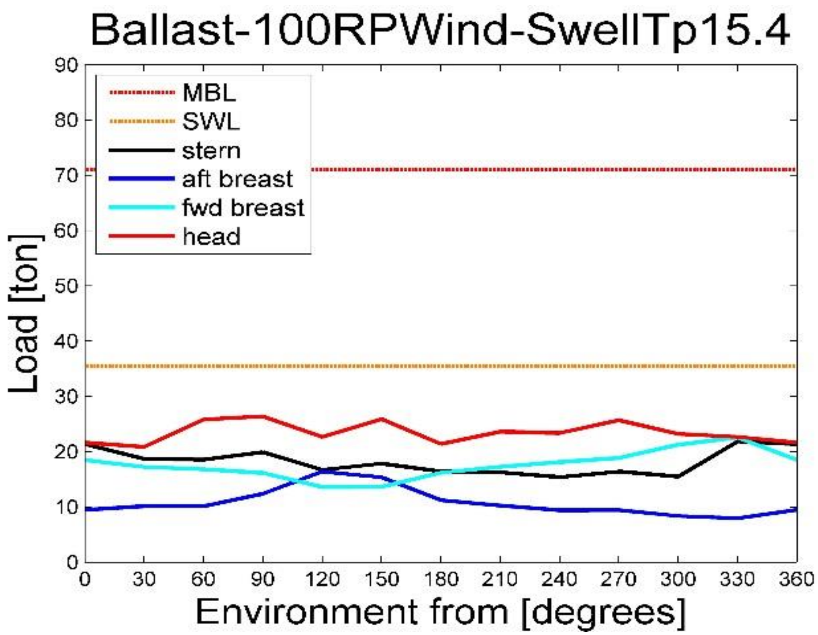
- Hydrodynamic analyses in Wamit
  - Added masses, wave loads and wave drift loads
- Simulation of the response to 3 h storms using SIMO (non-linear time domain simulations)
  - Combined dynamic action from wind, wind waves, swell, current

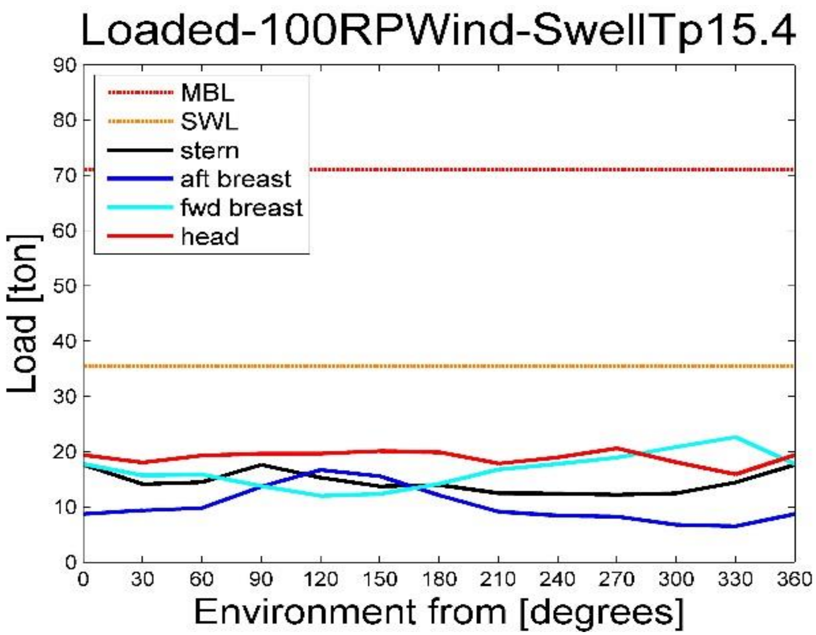
| | Loaded | Ballast |
|---|---|---|
| Extreme | 5 x 12 cases | 5 x 12 cases |
| omnidirectional wind | 7 x 12 cases | 7 x 12 cases |

# Eigen periods

| | T [sec] | 7.27 | 7.88 | 8.17 | 14.9 | 15.81 | 36.36 |
|---|---|---|---|---|---|---|---|
| Ballast | SURGE | -0.03 | -0.01 | -0.01 | -0.07 | 0.24 | 1 |
| | SWAY | -0.01 | -0.02 | 0.04 | 0.35 | 1 | -0.1 |
| | HEAVE | 0.28 | -0.05 | -0.08 | 0.01 | 0.03 | 0 |
| | ROLL | 1 | -1 | 1 | -0.09 | -0.1 | 0 |
| | PITCH | 0.29 | 0.19 | 0.08 | -0.03 | 0.02 | 0 |
| | YAW | 0.03 | 0.02 | 0.01 | 1 | -0.71 | 0.2 |
| Loaded | T [sec] | 9.22 | 11.62 | 12.84 | 20.22 | 24.65 | 52.59 |
| | SURGE | -0.09 | 0.01 | 0 | -0.01 | 0.41 | 1 |
| | SWAY | 0.2 | 0.02 | -0.02 | 0.4 | 1 | -0.1 |
| | HEAVE | 0.34 | 0.41 | -0.02 | -0.01 | -0.01 | 0 |
| | ROLL | 0.24 | 1 | 1 | 0.39 | 0.76 | 0 |
| | PITCH | 1 | -0.31 | 0.01 | -0.02 | 0 | 0 |
| | YAW | 0.17 | 0.02 | -0.01 | 1 | -0.85 | 0.2 |

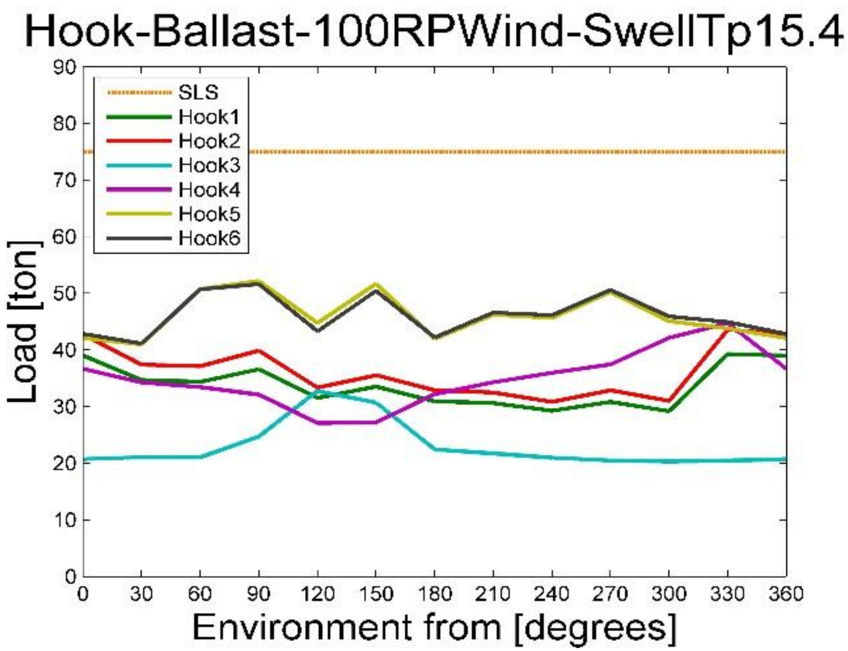
# Extreme environment – Mooring loads

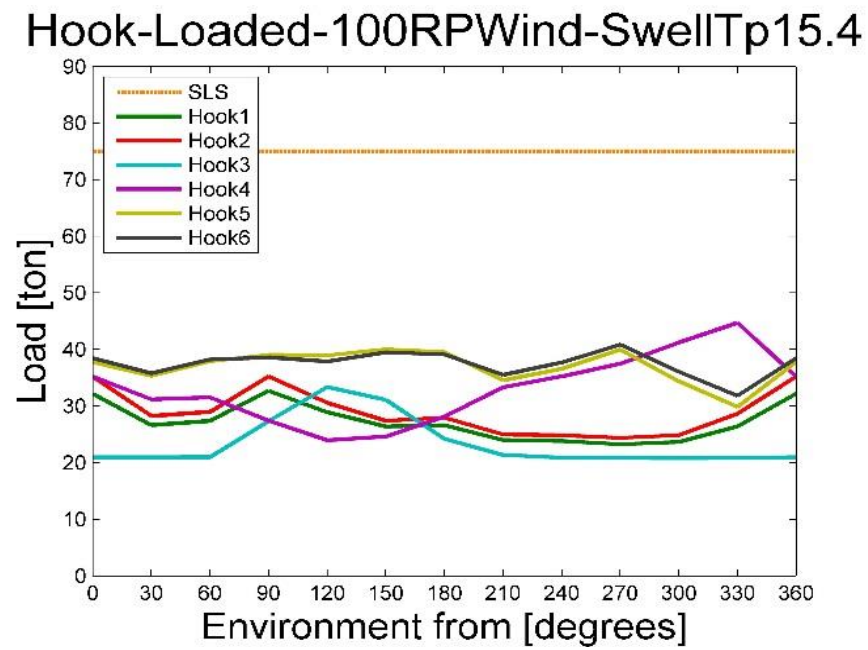



- Loads within SWL

# Extreme environment – Hook loads




- Loads within SWL

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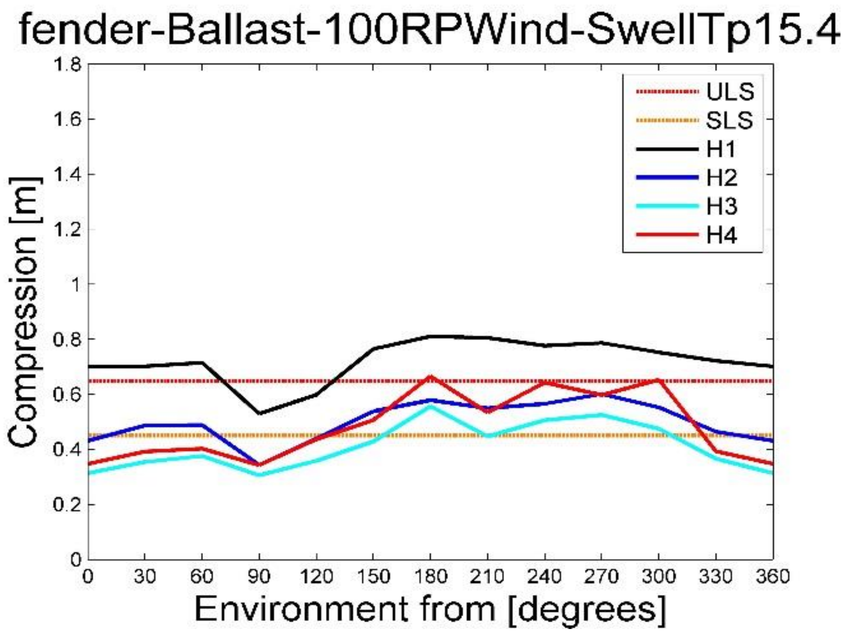
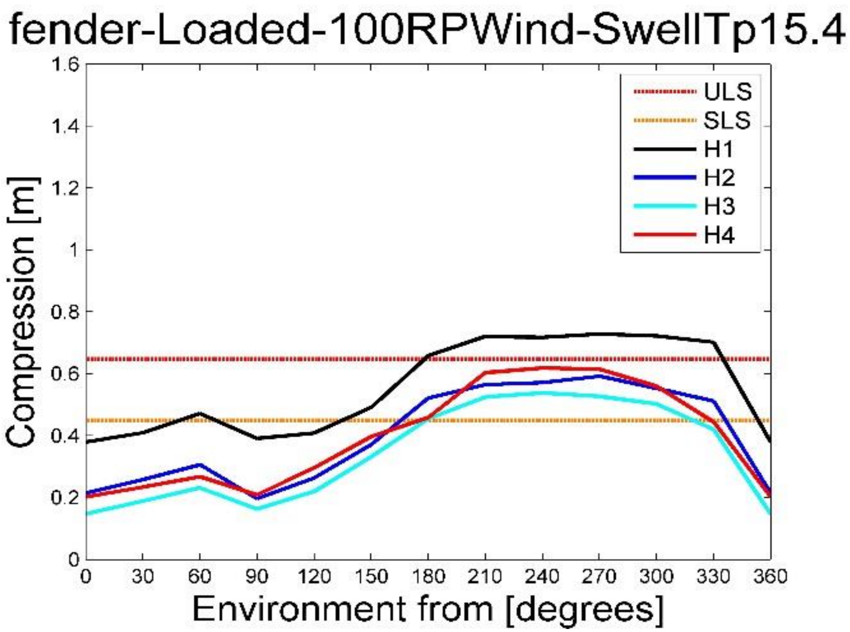
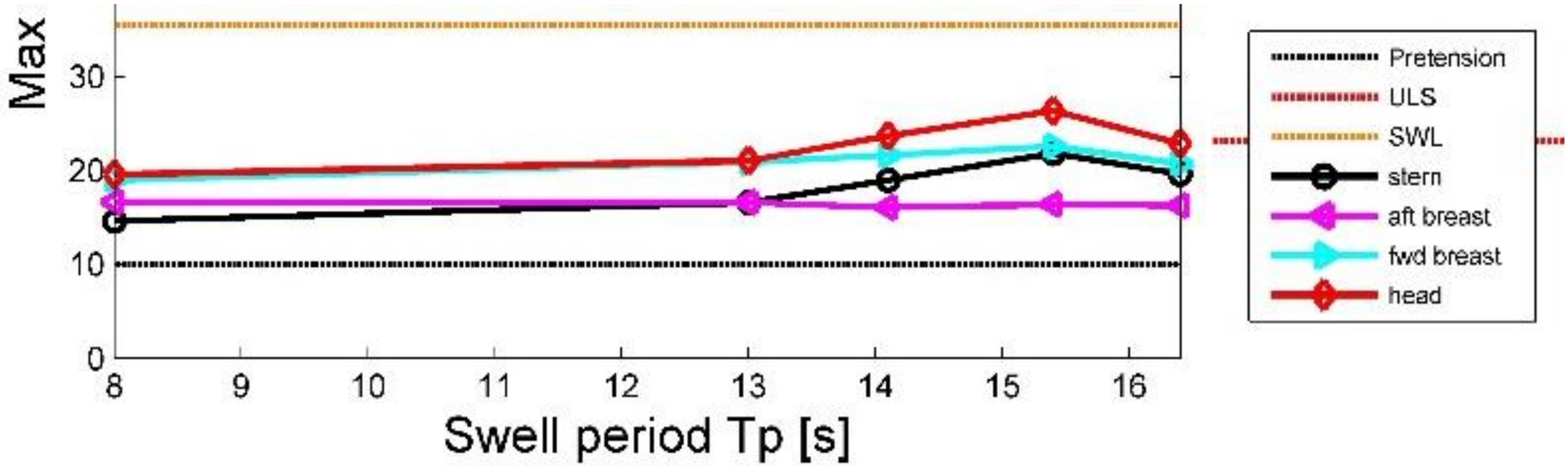
# Extreme environment – Fender compression



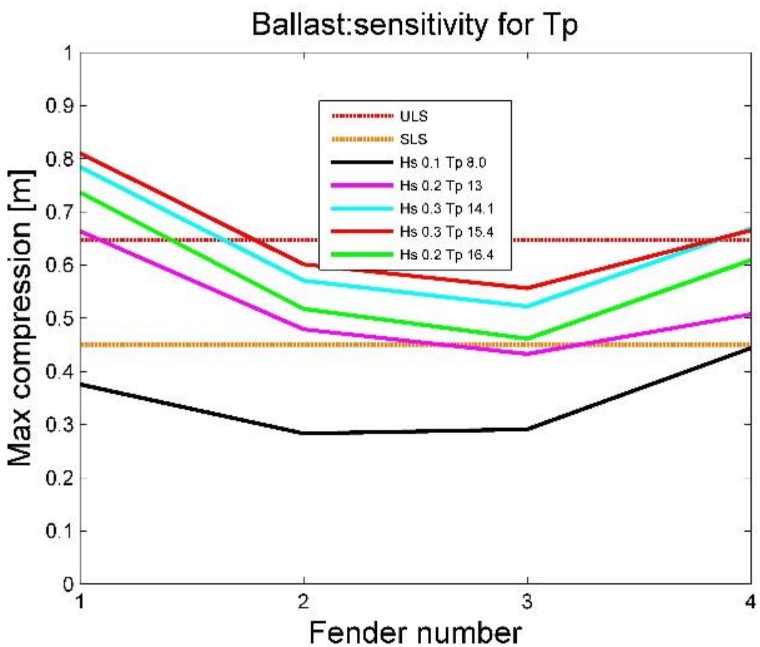

- Compressions exceed design compression limits for both ballast and loaded.

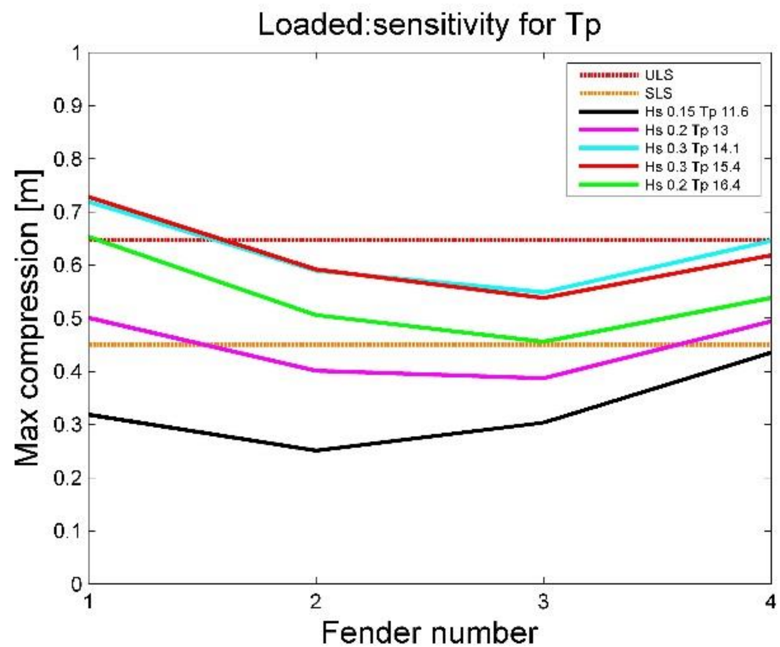
# Extreme environment –swell & mooring lines




- 15.4 s gives highest response (highest swell height; sway, yaw and roll excitation)
- Up to 40 % increase from the lower periods for stern and bow lines

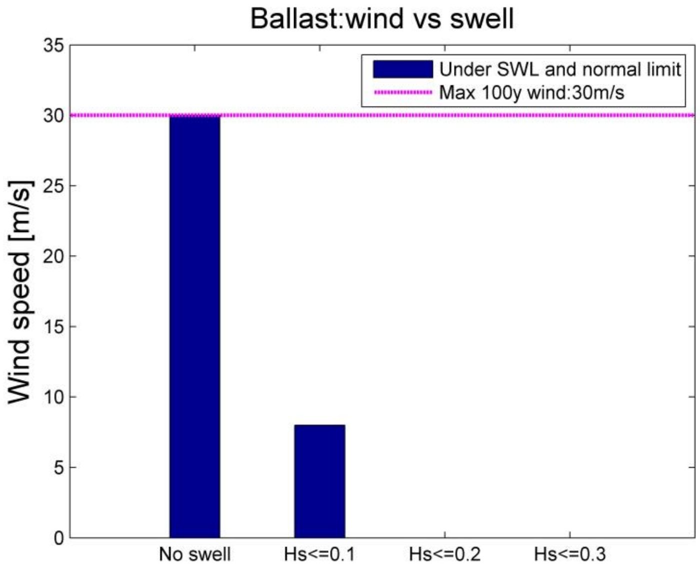
# Extreme environment –swell & fenders

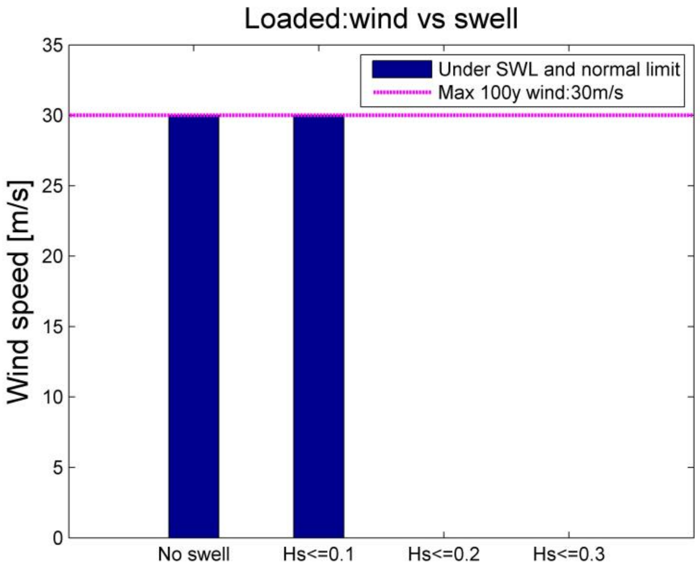



- Both loaded and ballast conditions are sensitive to swell heights
- 15.4 s gives highest response (highest swell height; sway, yaw and roll excitation)

# Maximum omni wind vs swell height

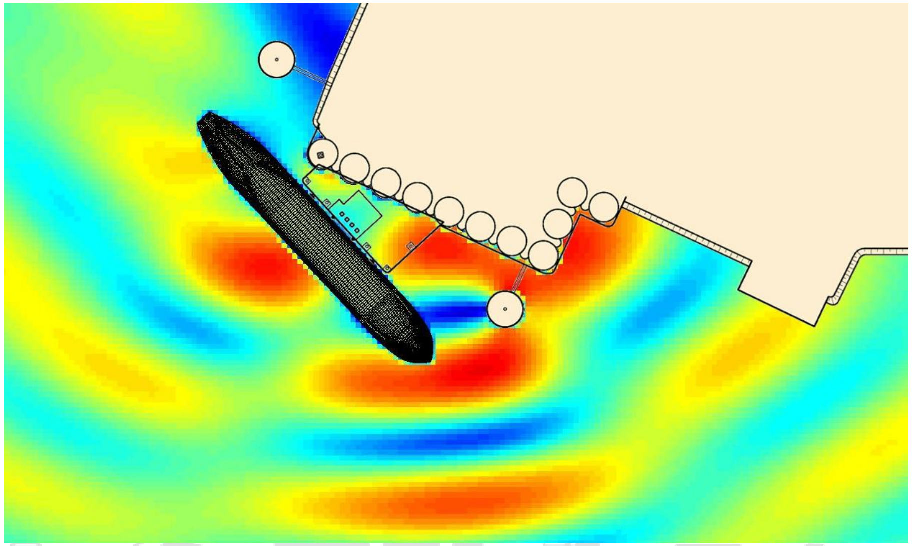



- No swell (no waves with long periods)
  + Max wind wave: $H_s$ = 1.7 m, $T_p$ = 4.3 s (30 m wave length, local max 4-5 m)
  + Max wind speed: 30 m/s (1 h, 10 m)
  + Max current speed: 0.7 m/s
- Swell present (200 – 400 m wave length)
  - Up to 0.1 m incoming wave height – operation possible, limited to 8 m/s wind speed in ballast (1-2 m local max short wave height)
  - Higher swell (rare event) – no operation

# Summary

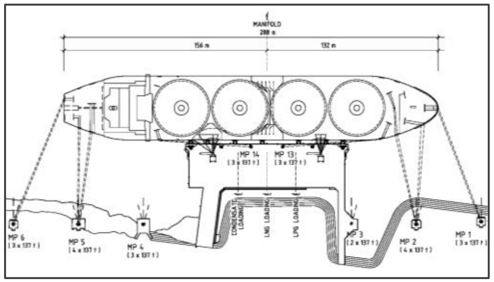
- Reflection of waves on the old quay front result in higher wave heights, higher wave loads, and higher response
- Mooring lines and hook capacity are not limiting factors
  - Mooring lines of 71 t MBL are strong lines for a medium tanker
- Under effect of swell, fender compressions limit the operation



# Possile outcomes

- Assess effect of having more flexible fenders
  - Double collapsible zones
- Monitoring of swell
  - Difficult to measure
  - Forecasts from Met office

# Port planning – pier & jetty design



Mooring plan
Dynamic analysis