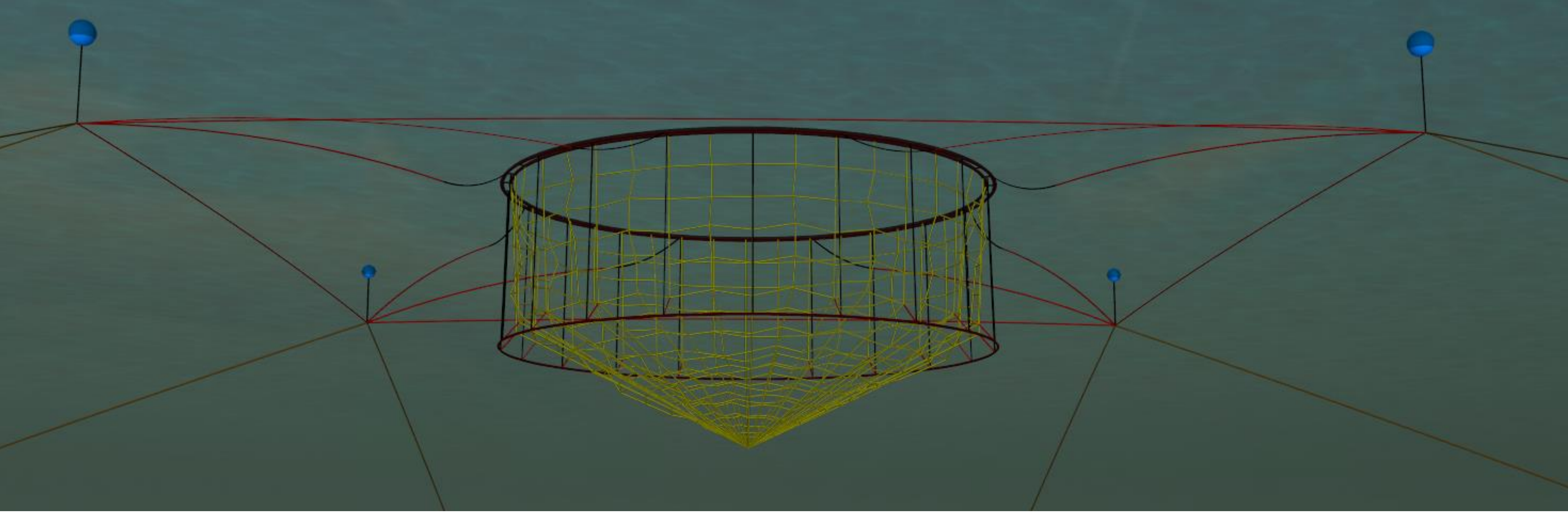


Analysis of floating flexible fish cages with ORCAFLEX/PYTHON

Short summary presentation, September 2017

SUMMARY

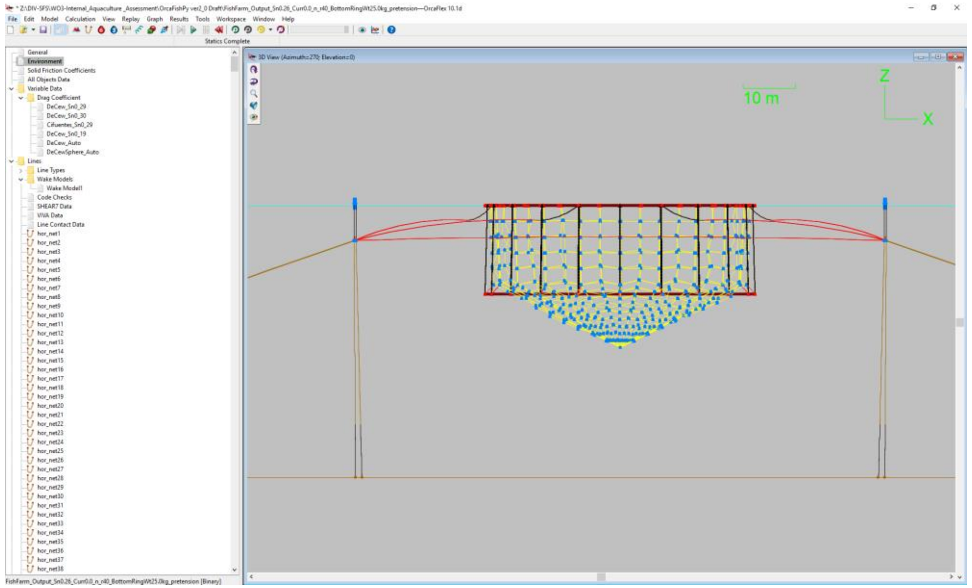
- Purpose of this presentation is to document analysis of floating flexible fish cages performed in ORCAFLEX
- Comparison with model tests, and alternative numerical methods/software, are presented
- The conclusion is that ORCAFLEX is fully capable of accurately predicting loads and deformations on floating flexible fish cages

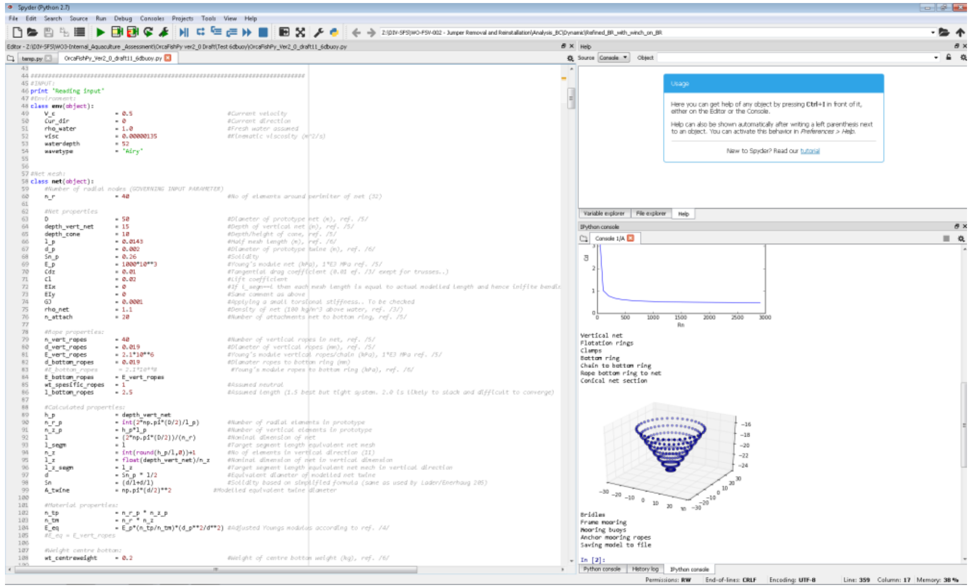
Analysis of Fish Cages in ORCAFLEX

SOFTWARE

- ORCAFLEX (version 10.1d):
  - Static and dynamic analysis program for modelling the behavior of a wide variety of marine and offshore systems
  - Considered worldwide state-of-the-art for complex non-linear time domain analysis
  - Includes options for wake modelling and implementation of variable data
  - Allows for large deformations
  - Includes extensive PYTHON API library
  - More info: www.orcina.com

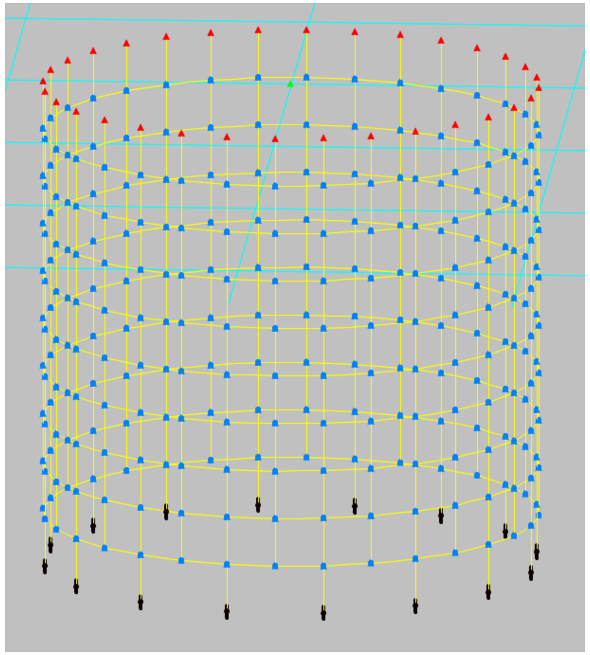
- PYTHON (version 2.7.12):
  - Open source programming language used for automation of the modelling of the nets
  - Enables easy variation of all input parameters as required





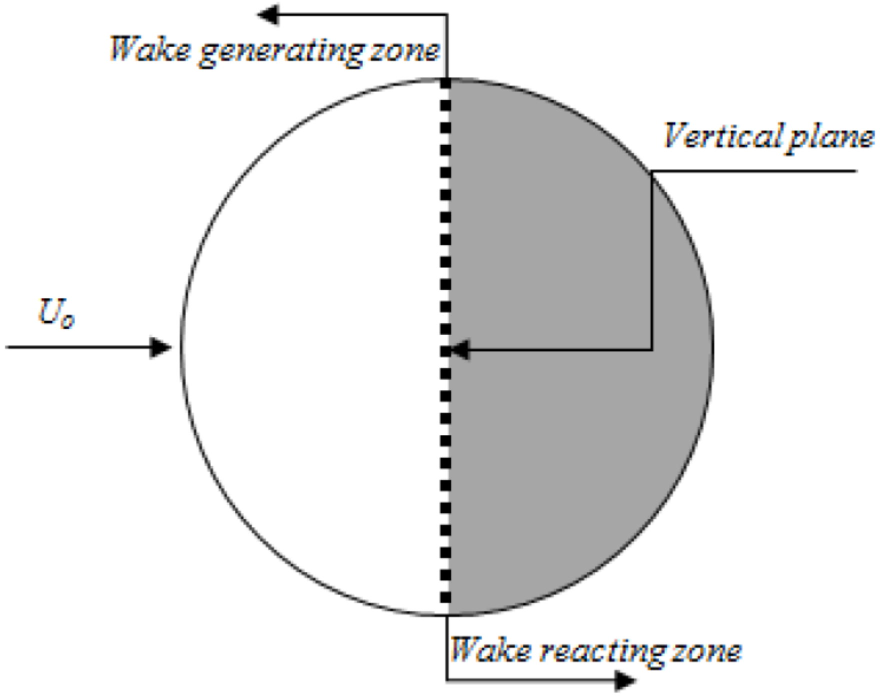
EQUIVALENT NET MESH

- A group of twines in physical net is represented by an equivalent line element
- Line elements are massless springs with two nodes at the end where mass and buoyancy are lumped
- Length of line elements is defined by an equivalent number of radial elements (typically 40)
- Axial stiffness based on adjusted Young's modulus
- Drag loads according to Morison's equation with drag diameter resulting in same solidity as physical net. Cross flow principle is applied
- Wake model and Reynolds dependent drag coefficients (described later)



WAKE MODEL AND DRAG COEFFICIENTS

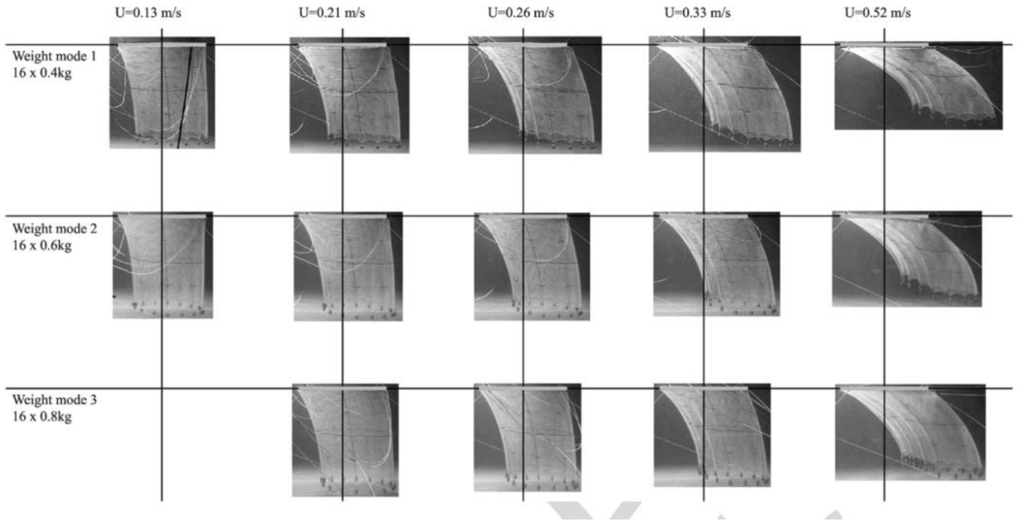
- The Blevins wake model is implemented by Orcina in Orcaflex
- This is an analytic model that models velocity and drag reduction, and also models the wake lift force that tends to draw the downstream object into the centre of the wake
- To apply the wake model, the cage is divided in two sections by a vertical plane perpendicular to the current direction
- Upstream elements generate wake and downstream elements react to wake
- Reynolds dependent drag coefficients implemented
- For high deformation nets, additional adjustments are included



Verification of current forces on simple flexible net structure

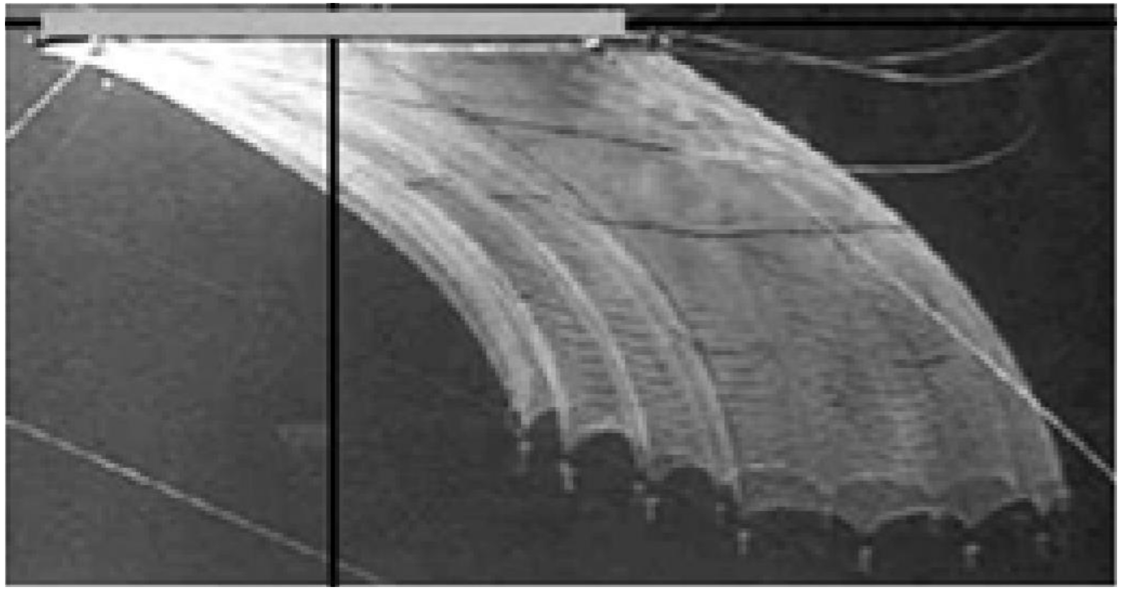
MODEL TESTS

- Model test of simple flexible net cages with bottom weights has been performed with different solidities, bottom weights and current velocities

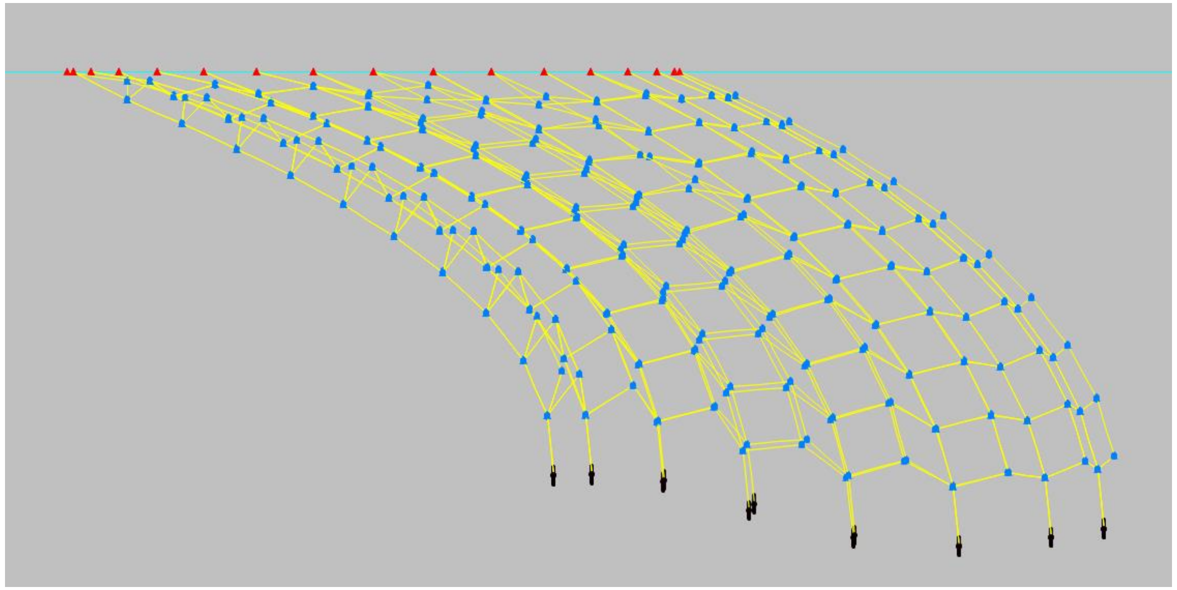


NET DEFORMATIONS

Model test:

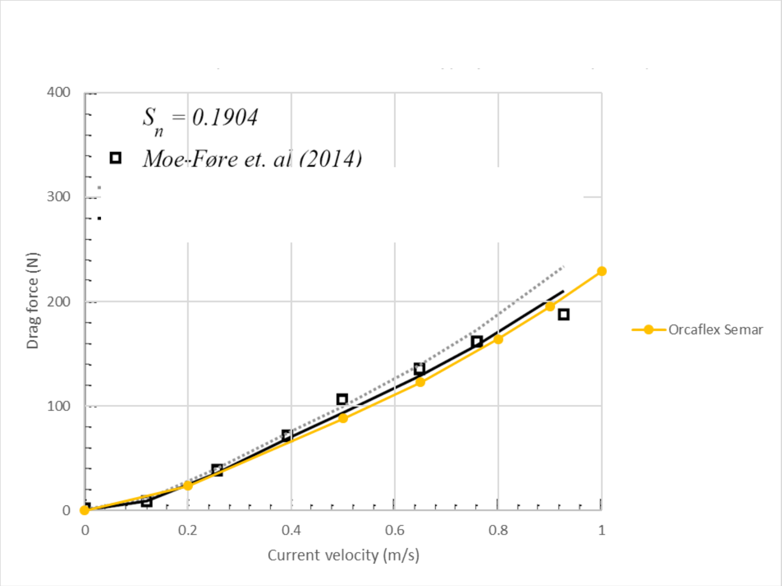


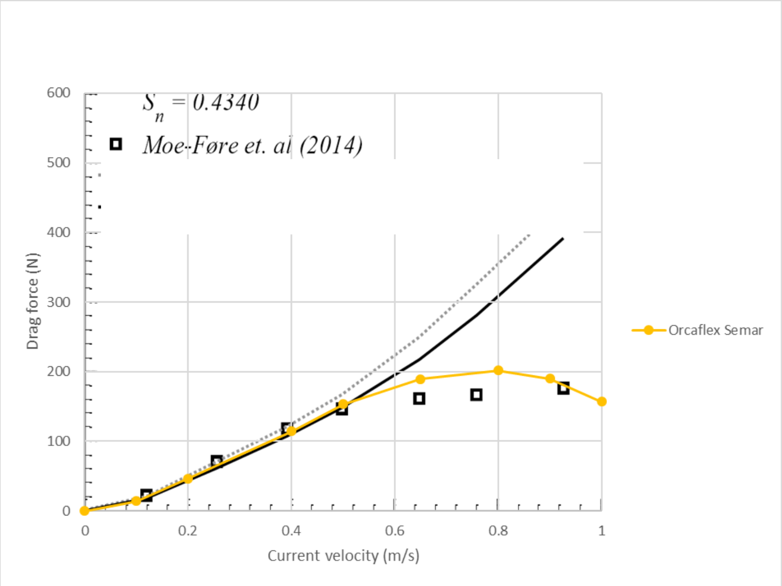
ORCAFLEX:



RESULTS

- Model is documented for solidity 0.19, 0.25, 0.3 and 0.43. Drag loads for the two extremes are presented in figures
- ORCAFLEX is able predict global loads for all solidity ranges and current velocity up to 1.0m/s
- This simple model validates the equivalent net model implemented in ORCAFLEX



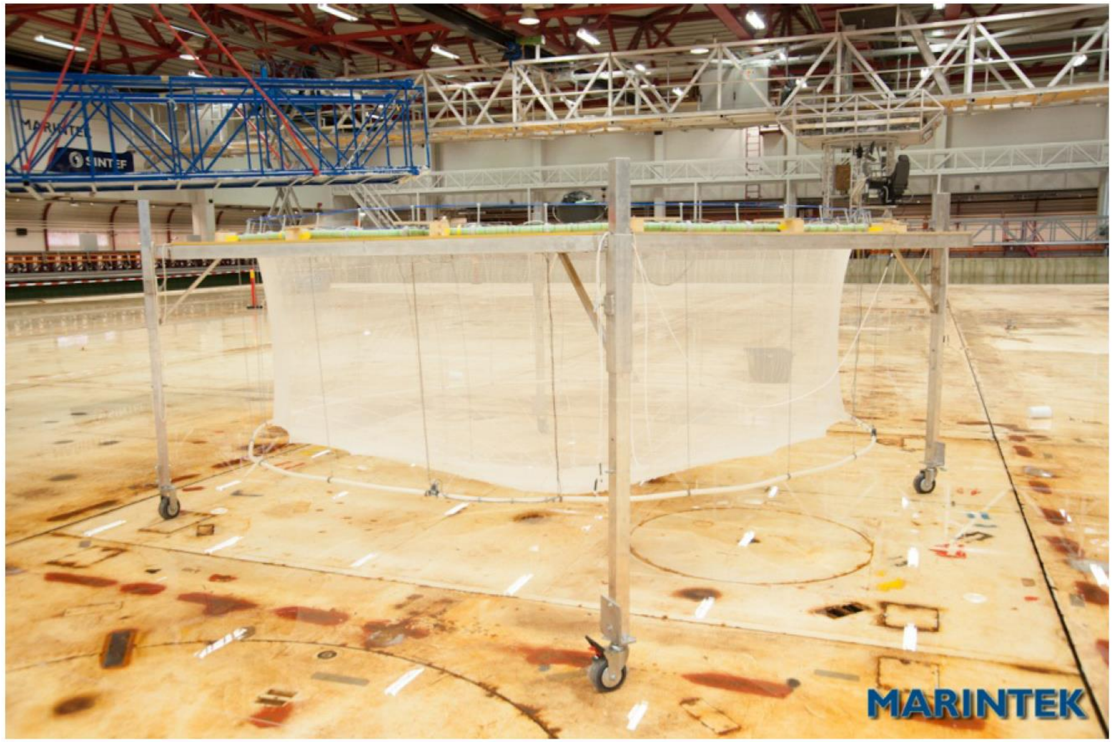


Verification of wave and current forces on standard net cage system

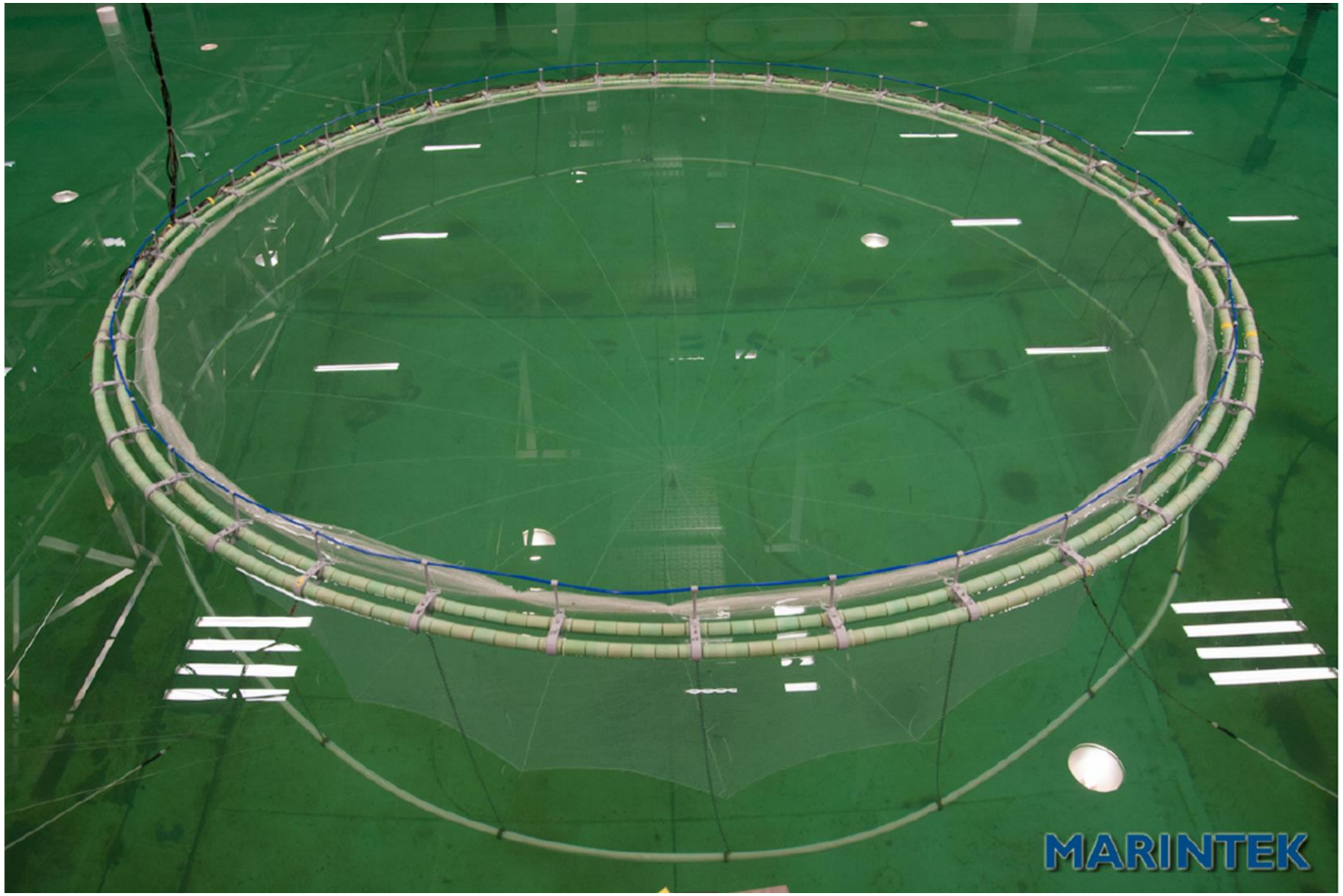
MODEL TEST

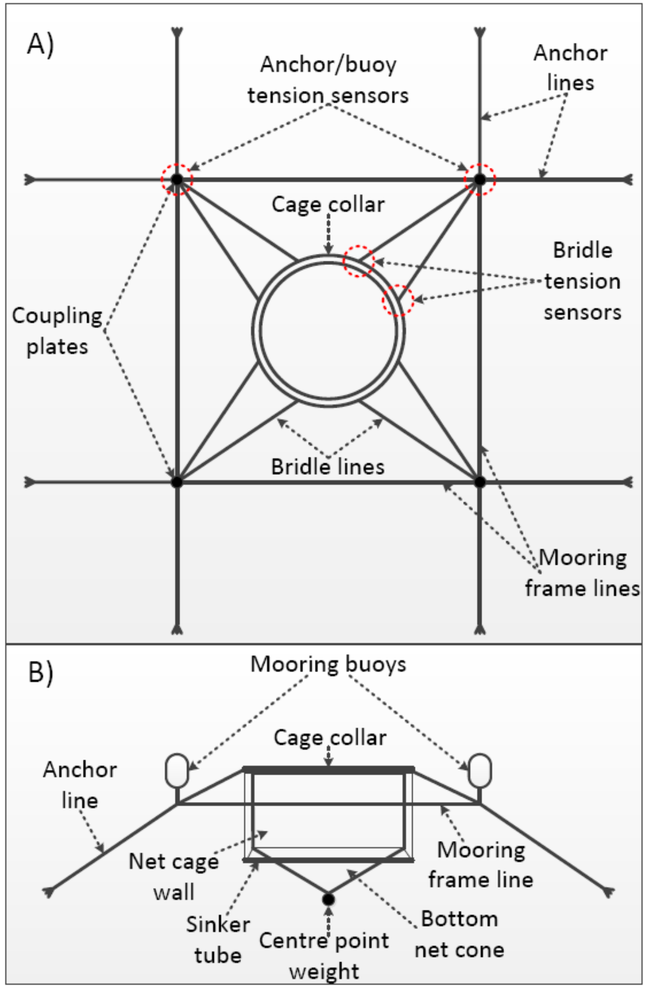
- Tests performed by MARINTEK ocean basin May 2013 with scale 1:16
- Three alternatives were tested:
  - 1) vertical chains between floating ring and bottom ring
  - 2) rope between floating ring and bottom ring
  - 3) bottom ring attached directly to net
- Net solidity 0.26
- Varying distributed weight of bottom ring: 25 and 50 kg/m
- Current only, regular and irregular waves

MODEL TEST



MODEL TEST


MARINTEK

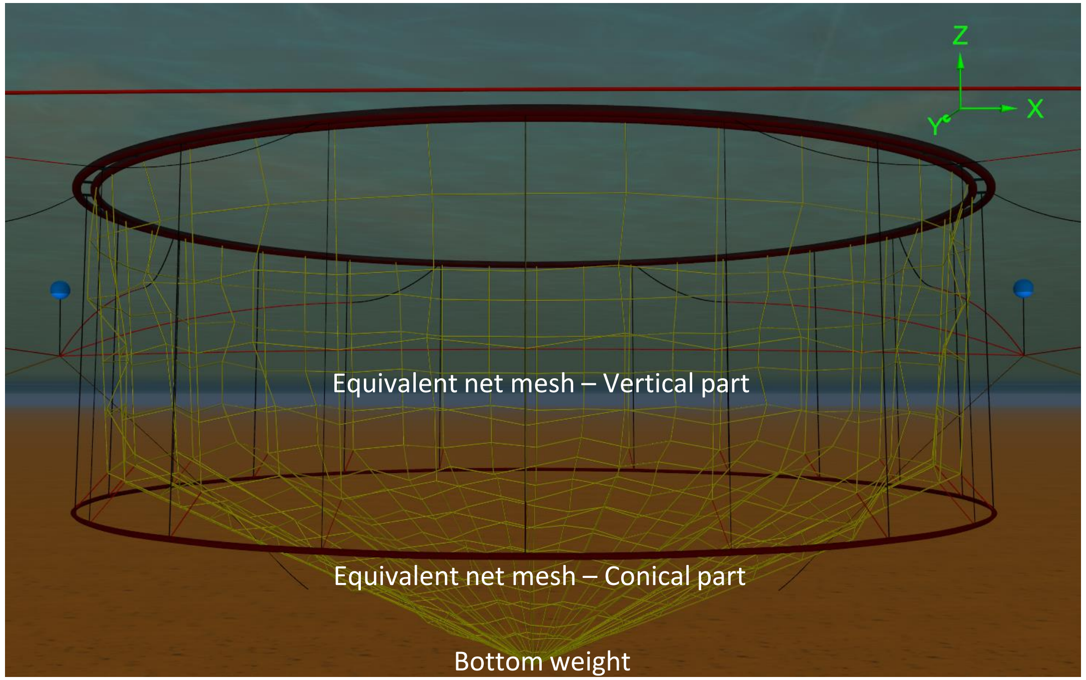

A)
Anchor/buoy tension sensors
Anchor lines
Cage collar
Bridle tension sensors
Coupling plates
Bridle lines
Mooring frame lines
B)
Mooring buoys
Cage collar
Anchor line
Net cage wall
Mooring frame line
Sinker tube
Centre point weight
Bottom net cone

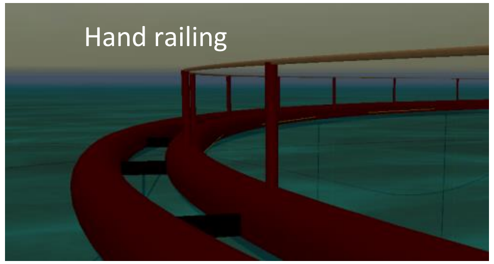
NUMERICAL MODEL

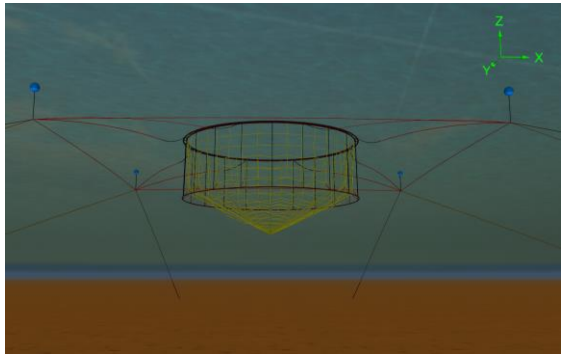
- Alternative 1), e.g. chains between floatation ring and bottom ring, are modelled in ORCAFLEX
- An equivalent net mesh with 40 radial elements, resulting in a total of 1160 equivalent elements, interconnected by buoys, is used
- Flotation ring, clamps, bottom ring, bottom weight, connection chains and ropes, and anchor lines, mooring buoys and bridles, are modelled in addition
- Main focus on comparison of current and regular waves with main analysis cases included in below table:

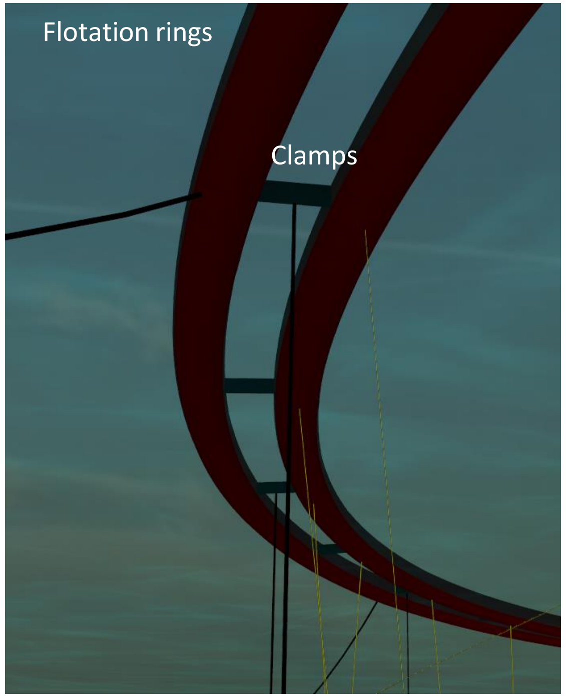
Case	$V_c (ms^{-1})$	T_w (s)	ζ_a (m)	ST (kgm^{-1})
C1	0.5	0.0	0.0	25
C2	0.7	0.0	0.0	50
W1	0.0	6.0	1.25	25
W2	0.0	8.0	1.25	25
CW1	0.5	6.0	1.25	25
CW2	0.5	8.0	1.25	25

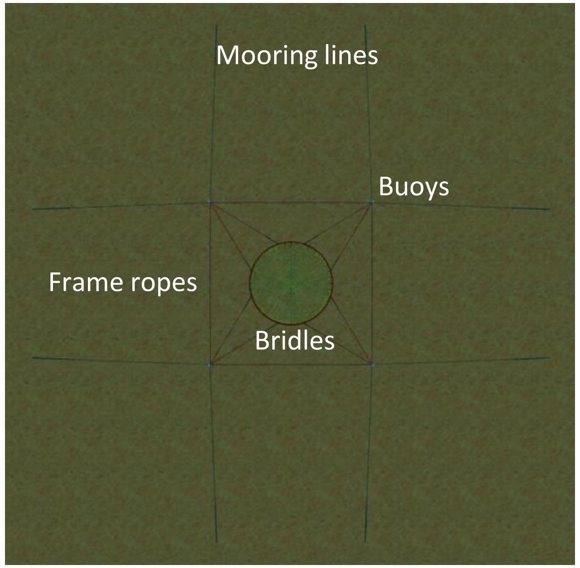
NUMERICAL MODEL

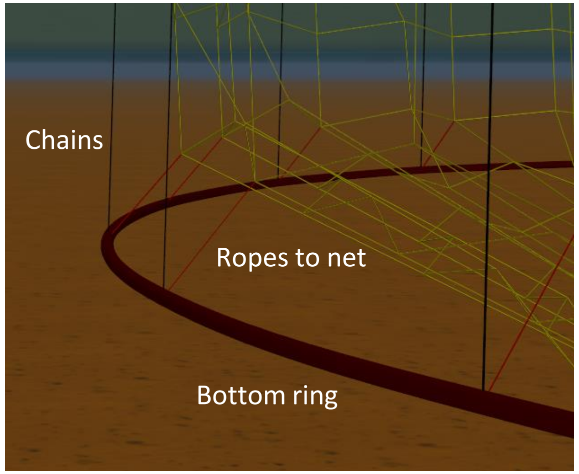






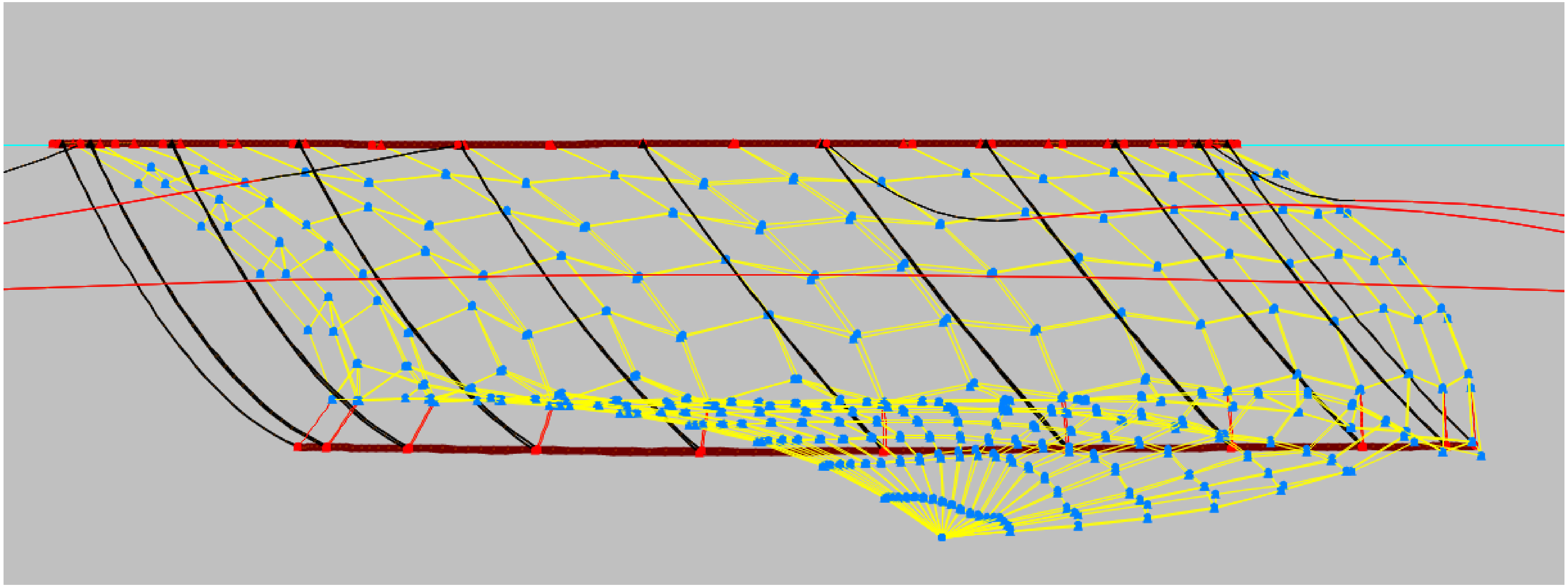




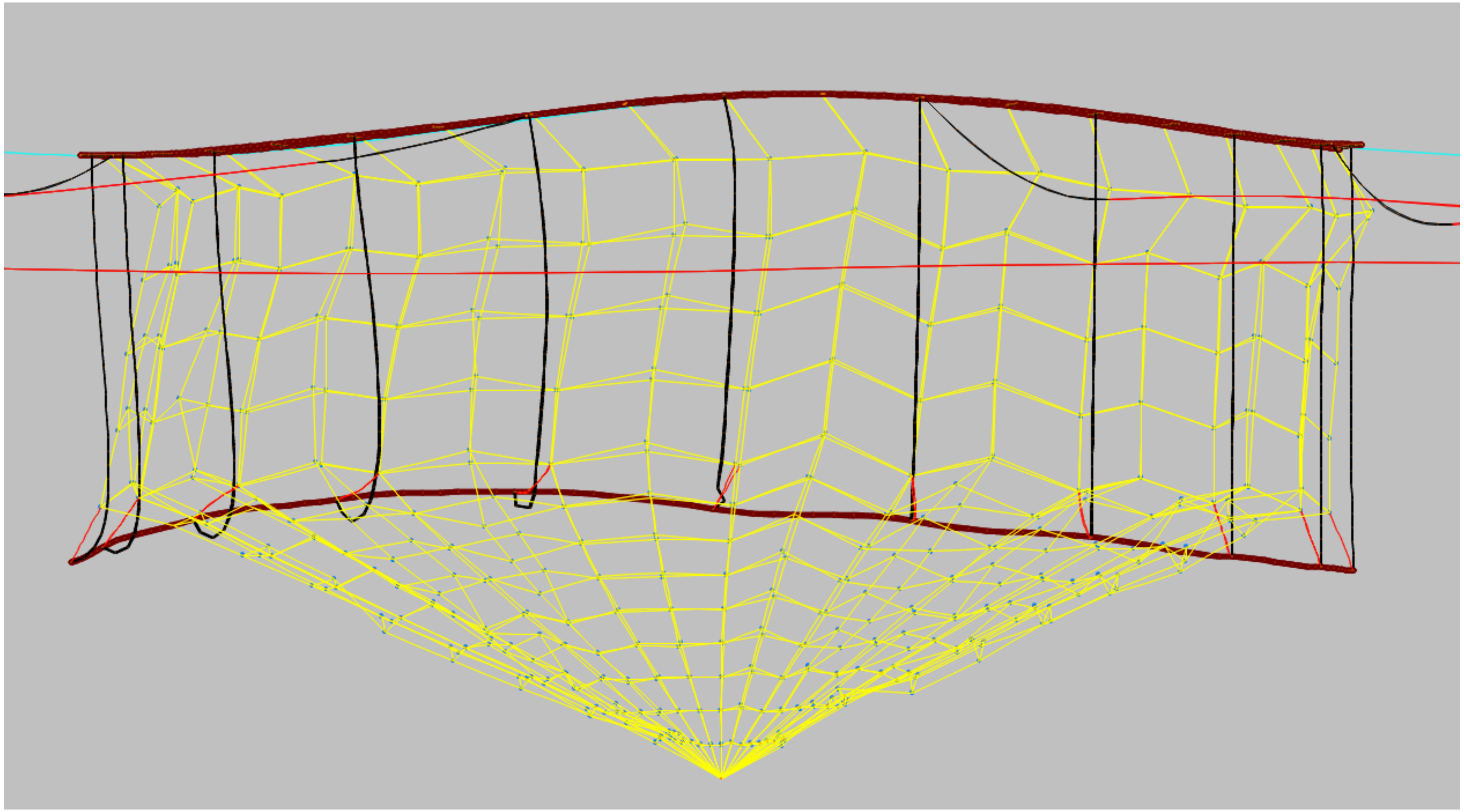


- Other configurations, e.g. without chains etc., is easily to implement if required

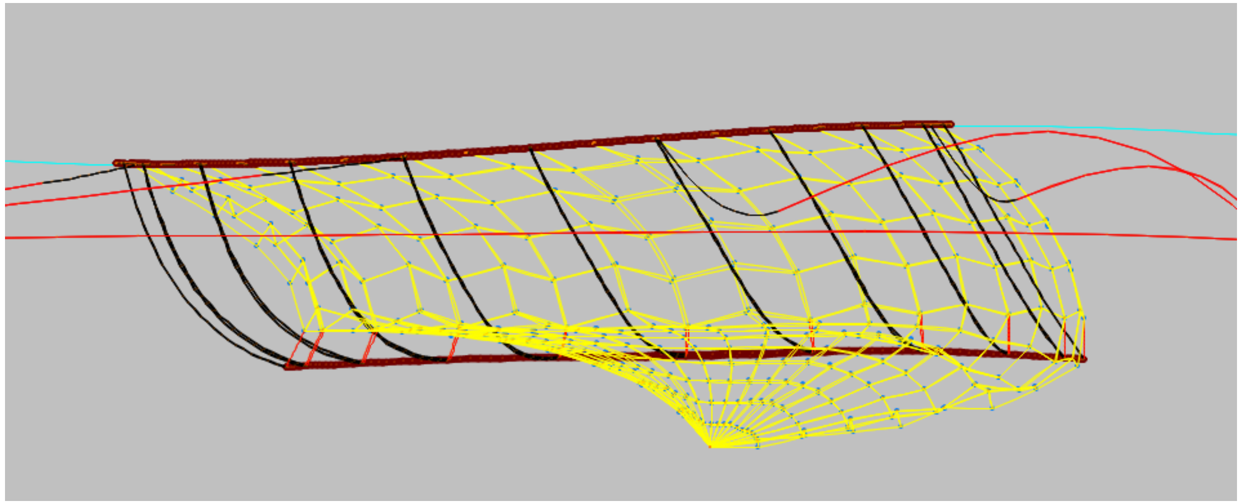
Case C2 - Current only (Vc=0.7m/s)

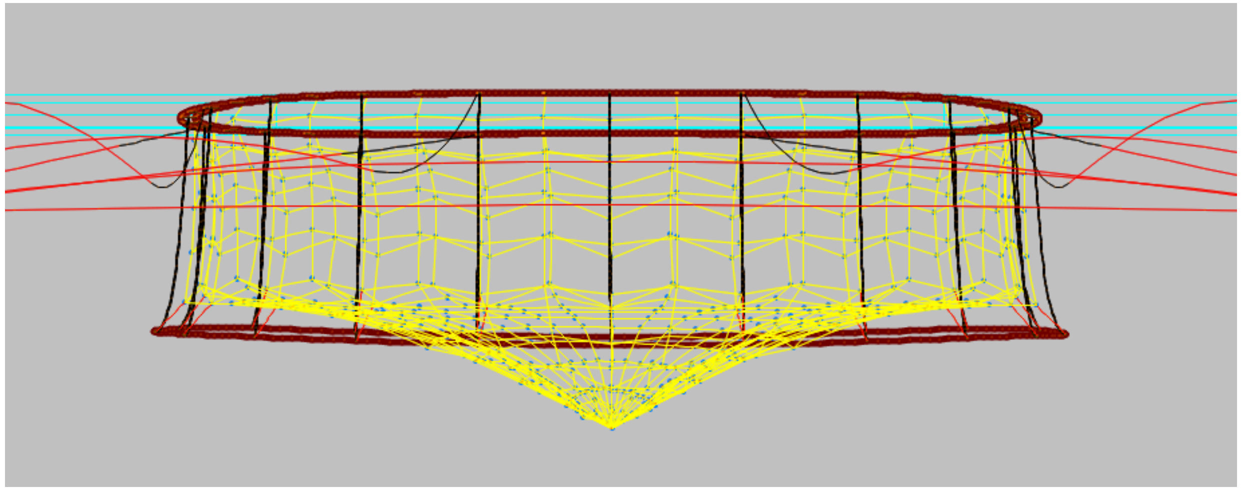


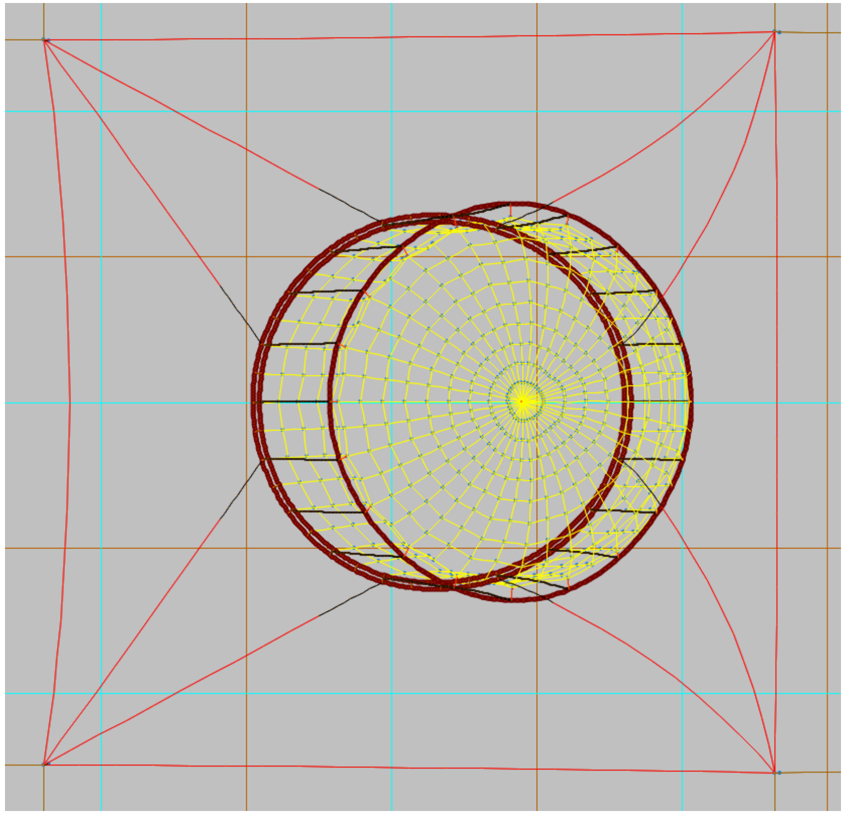
Case W1 - Regular waves (H=2.5m, T=6.0s)



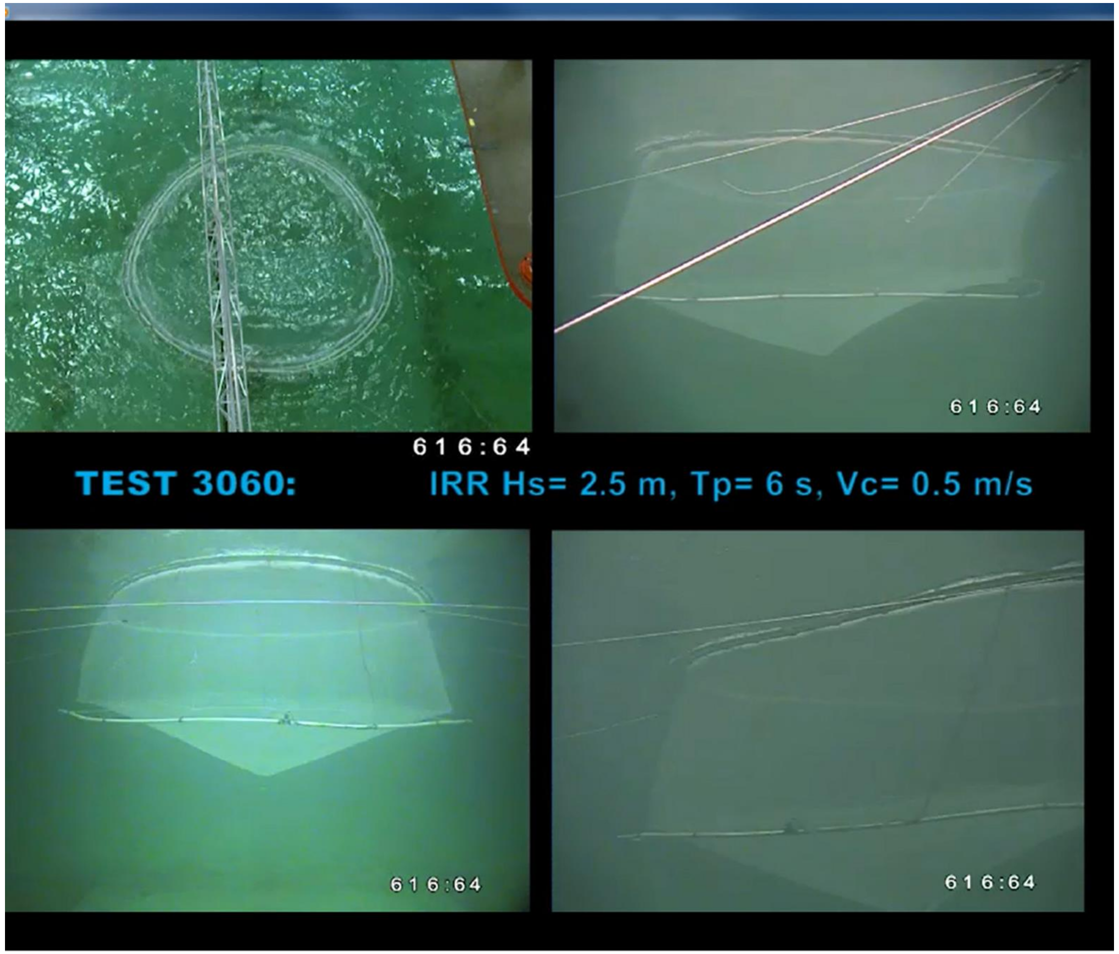
Case CW2 - Regular waves (H=2.5m, T=8.0s), Vc=0.5m/s

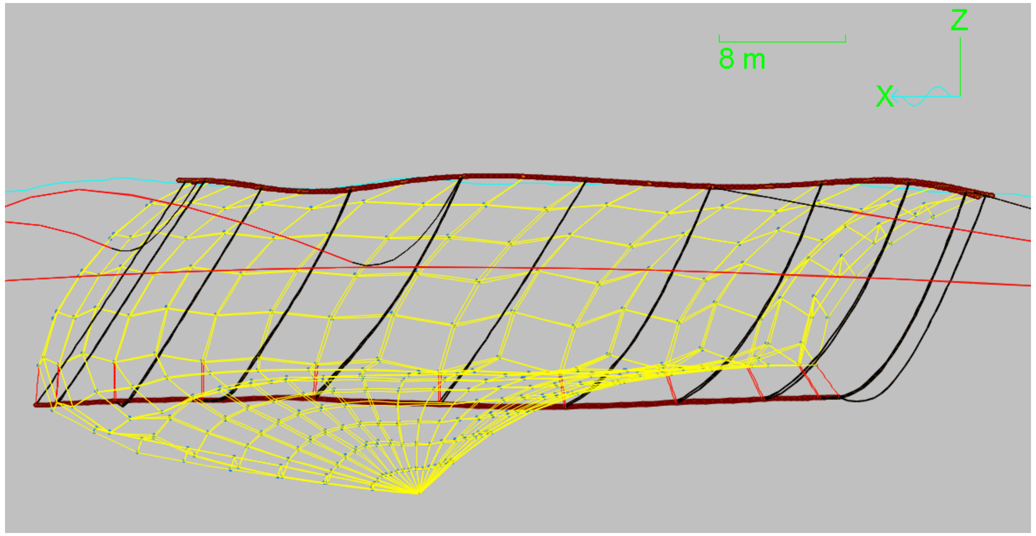






Irregular waves (Hs=2.5m, Tp=6.0s, gamma =2.0), Vc=0.5m/s



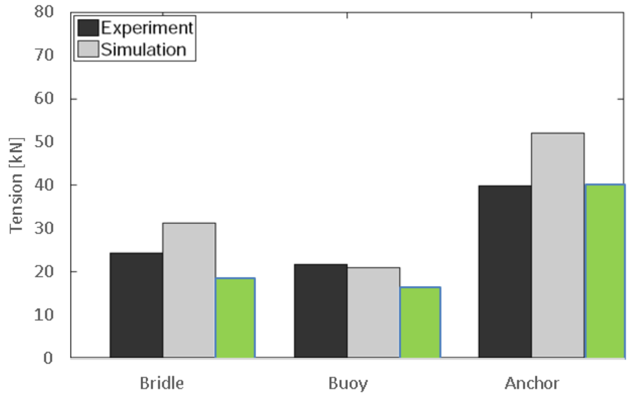


RESULTS

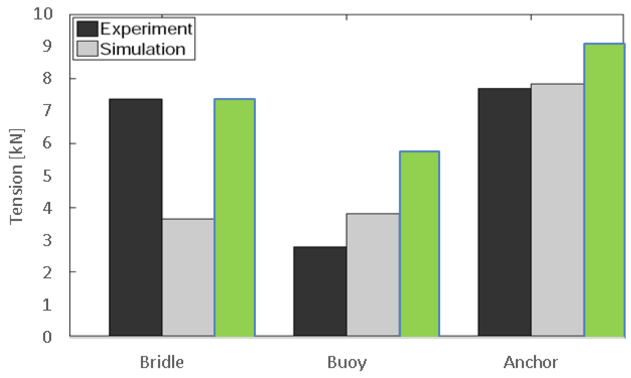
Experiments
Sintef Ocean – FhSim
SEMAR AS – Orcaflex

Case	$V_c (ms^{-1})$	T_w (s)	ζ_a (m)	ST (kgm^{-1})
C1	0.5	0.0	0.0	25
C2	0.7	0.0	0.0	50
W1	0.0	6.0	1.25	25
W2	0.0	8.0	1.25	25
CW1	0.5	6.0	1.25	25
CW2	0.5	8.0	1.25	25

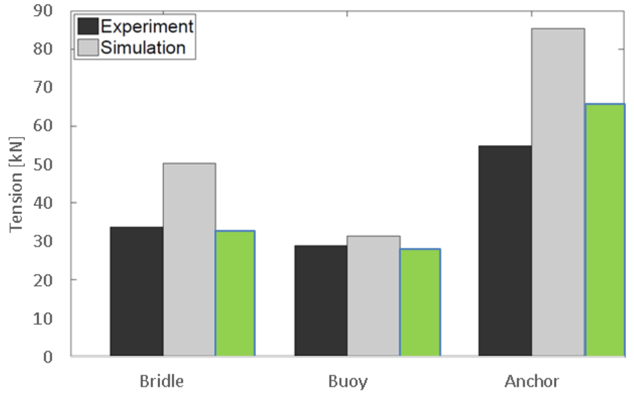
Case C1 (25kg/m, 0.5m/s)
Note: Average of static tension of two line measurements



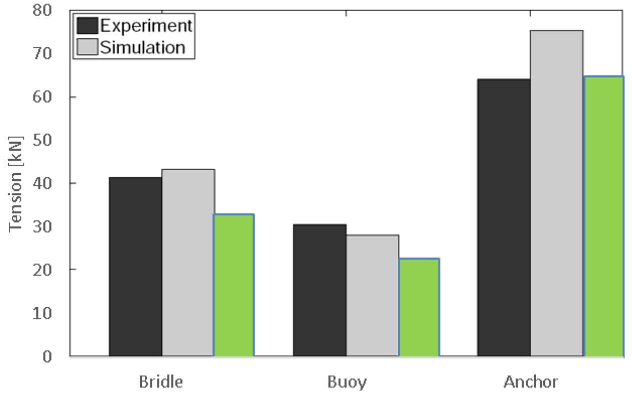
Case W1 (25kg/m, 2.5m 6s)
Note: Average of max tension (minus pretension) of two line measurements



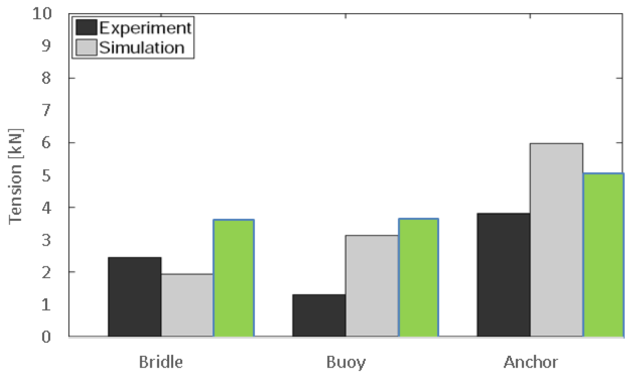
Case CW1 (25kg/m, 0.5m/s, 2.5m 6s)
Note: Average of max tension of the two line measurements



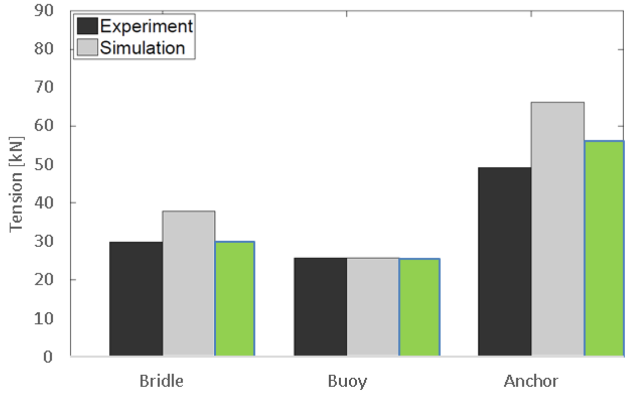
Case C2 (50kg/m, 0.7m/s)
Note: Average of static tension of two line measurements



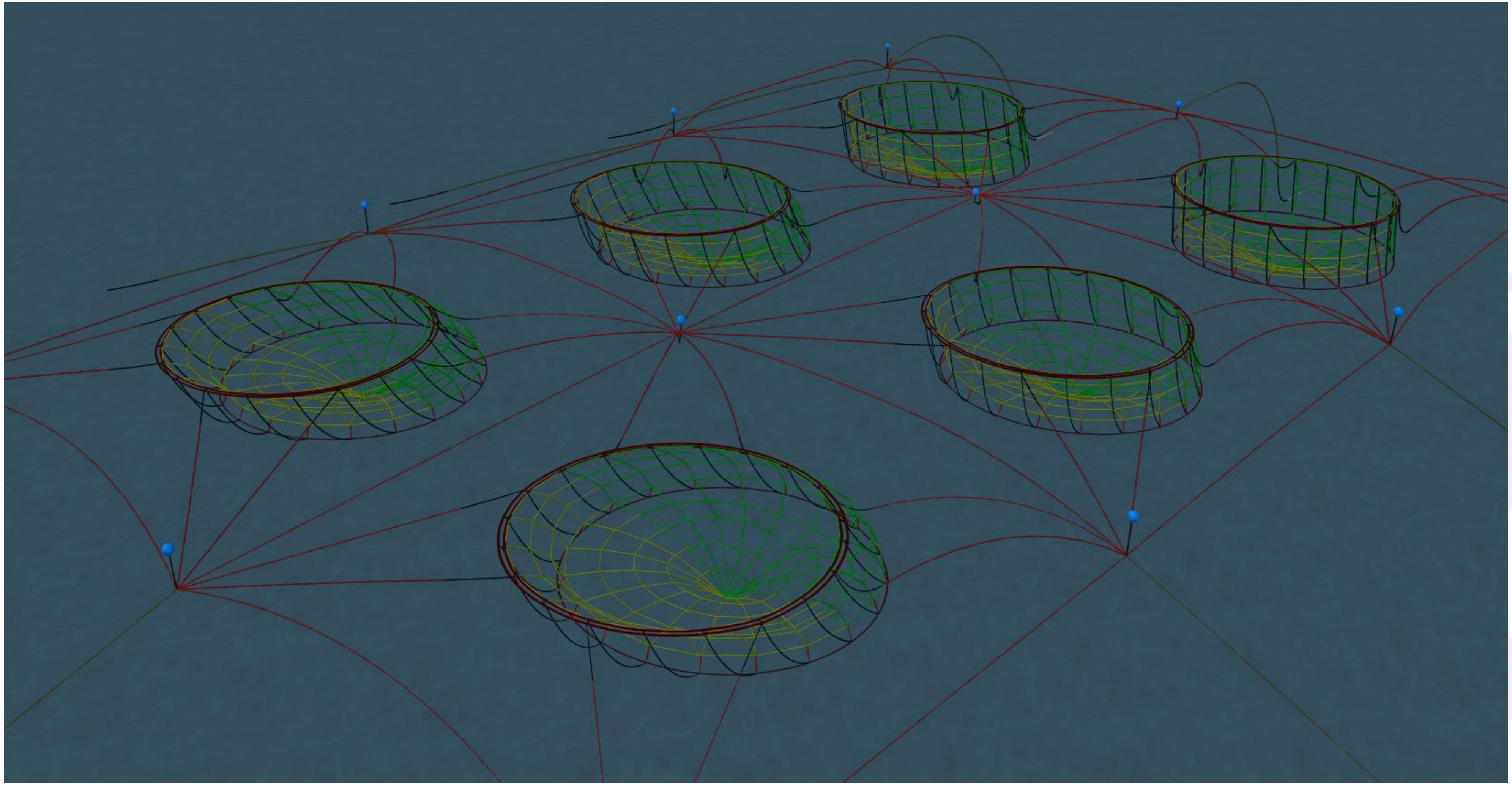
Case W2 (25kg/m, 2.5m 8s)
Note: Average of max tension (minus pretension) of the two line measurements



Case CW2 (25kg/m, 0.5m/s, 2.5m 8s)
Note: Average of max tension of the two line measurements



MULTIPLE CAGE ANALYSIS



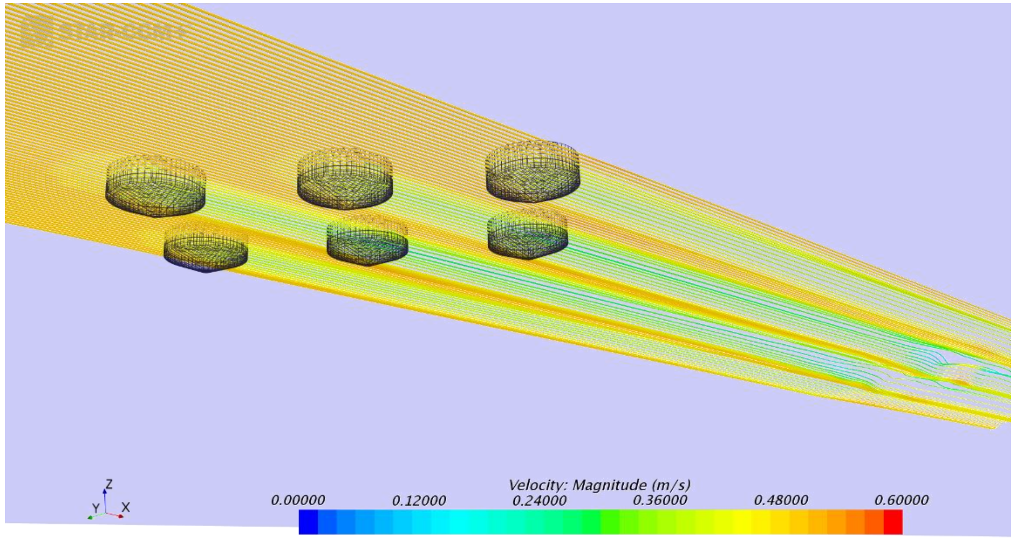
RESULTS

- The overall accuracy of the numerical model in ORCAFLEX compared with model test is very good
- Global loads, most accurately measured by the anchor loads, are close to equal for current only cases and slightly conservative when waves are included
- Loads in bridles are accurately described when waves are included, but slightly non-conservative for current only cases
- Loads in mooring buoys have not been evaluated in detail. The buoys are implemented by a simplified 3d buoy type object and increased accuracy is expected if a more refined model is used

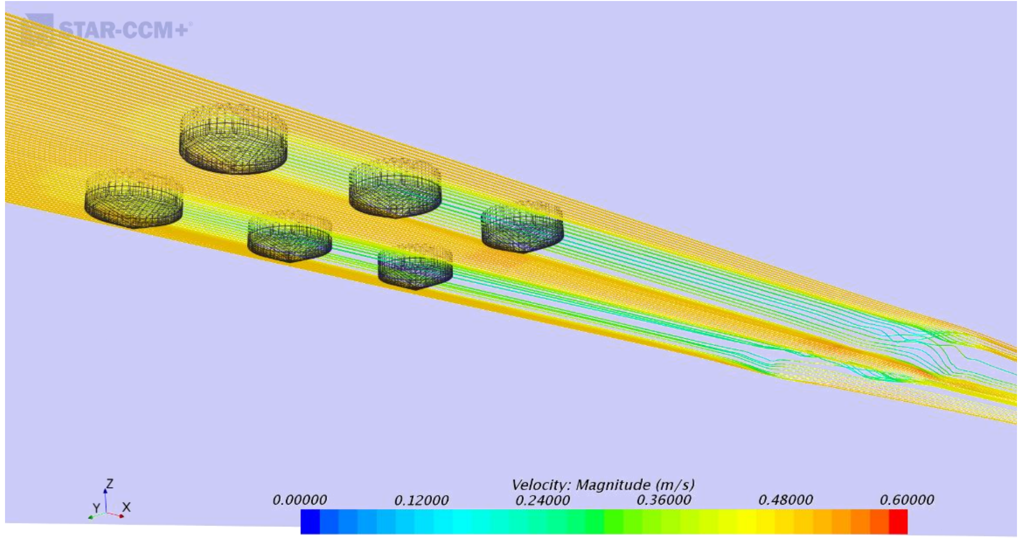
CFD

CFD

- Computational Fluid Dynamics (CFD) is utilized by SEMAR for advanced fluids calculations that otherwise cannot be performed without model tests, or as a cost saving supplement
- Possible applications for fish farming industry includes drag evaluations of net structures, and current reduction calculations on complete fish farm systems
- Results can be used as input to global analysis where these cannot otherwise be calculated



Solution Time 2000.1 (s)



Solution Time 2000.1 (s)

Conclusive remarks

CONCLUSION

- The overall conclusion is that it is fully feasible to analyze complex floating fish cages accurately by using ORCAFLEX
- This, in combination with modelling and automation by using PYTHON programming, enables efficient analysis of such systems
- SEMAR has access to running large analysis matrices on a dedicated 28 core analysis computer
- We also provide CFD analysis as stand alone evaluations or input to global analysis models