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Testing the critical link - Physical Testing of Dynamic Power Cables



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Supergen  Offshore
Renewable
Energy

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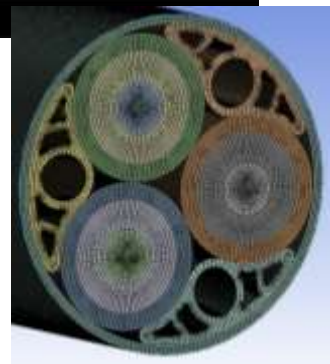
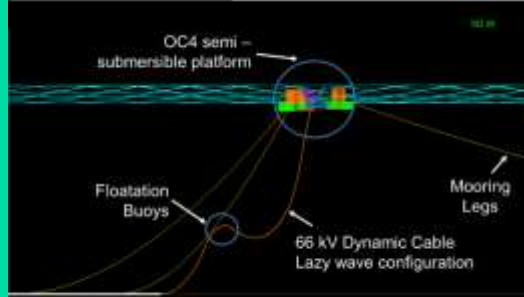
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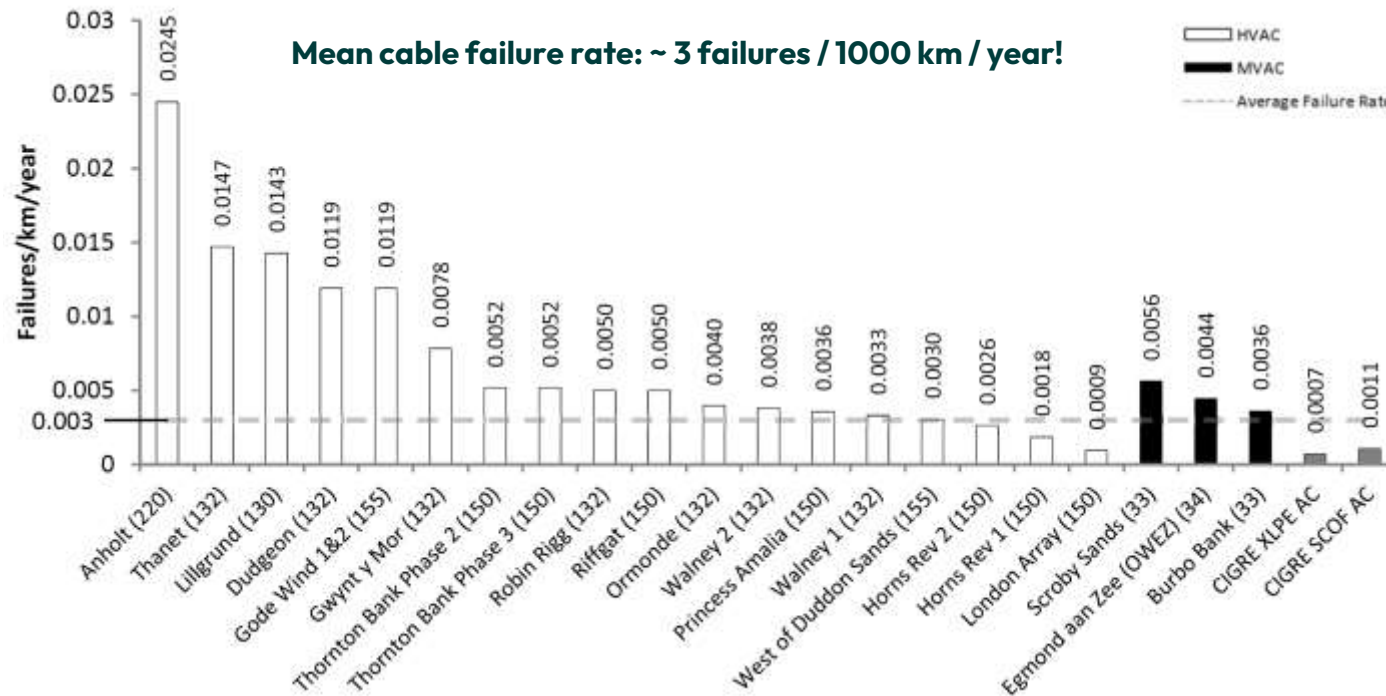
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Outline

- Challenge
- Coupled Hydrodynamic modelling
- Dynamic testing
 - Cable
 - Cable + Bend restrictor
 - Cable + Bend stiffener
- Discussion & Summary

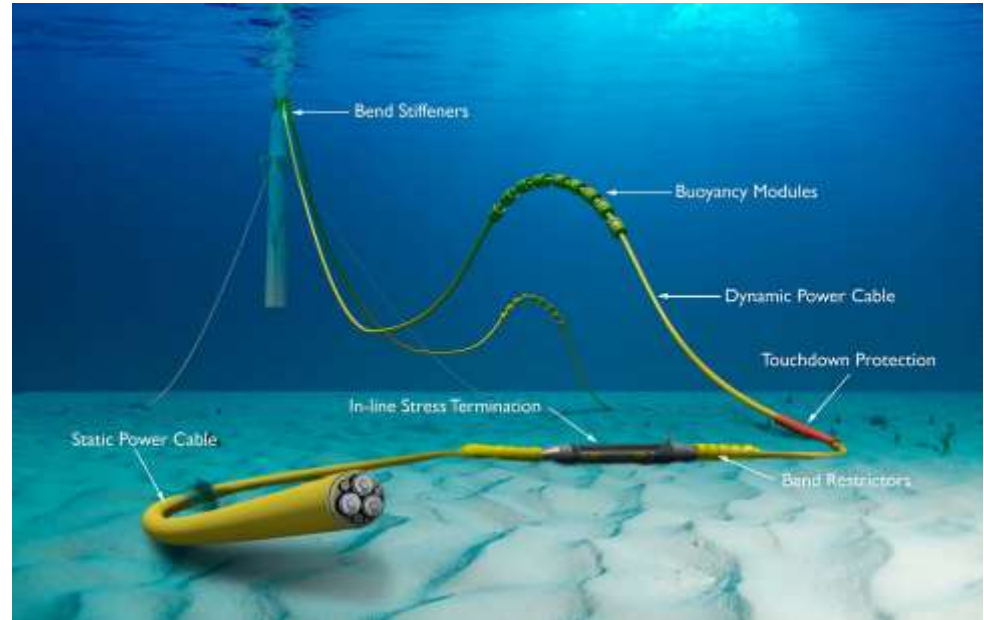


Cable failure rates



Dynamic power cables

- Key component for floating offshore renewables
- Complex heterogeneous structures
- Aim of Supergen ORE Hub WS4:
 - Improved characterisation of mechanical properties
 - Reduced-order modelling of global responses
 - Development of reference cable design (SRS2)

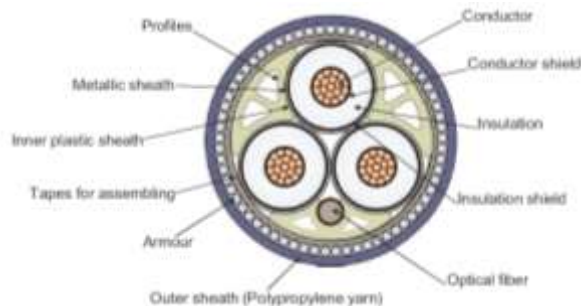


Joshua Bauer, NREL

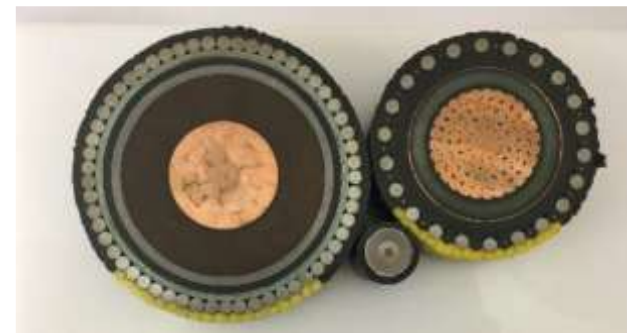
Cable Types



HVAC Array Cable vs. Export cable



Typical 3 core cable design



HVDC Interconnection cable

Parameter	Array HVAC cable	Export HVAC cable	HVDC cable
Outer diameter	110 - 160mm	250 - 320 mm	~ 150mm
Minimum Bend Radius (MBR)	~ 2 m	~ 5 m	Variable
Conductor cross-section	3 x 120 - 800 mm ²	3 x 800 - 1,400 mm ²	> 1,800 mm ²
Voltage rating	< 66 kV	132 - 345 kV	~600 kV

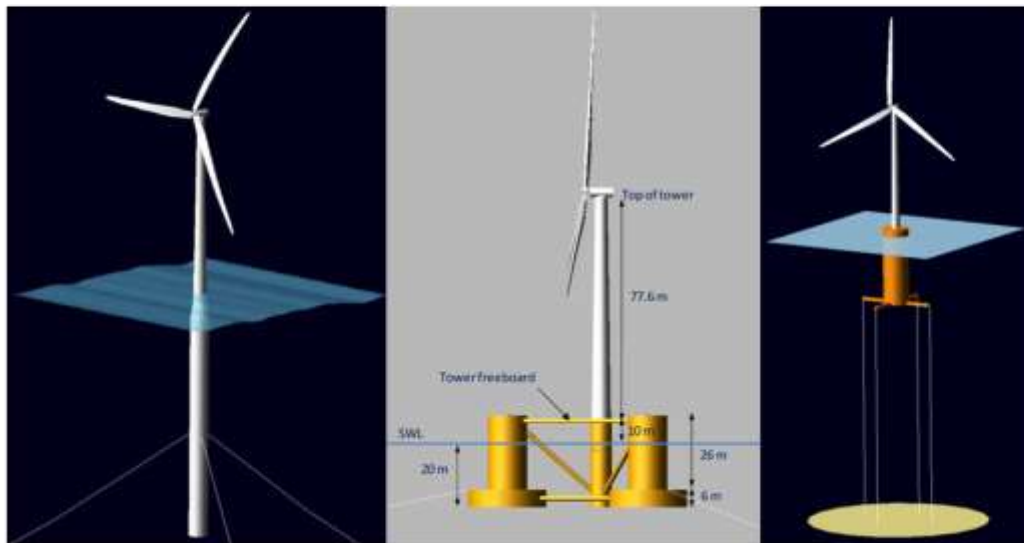
Coupled modelling

Existing dynamic Advanced Coupled Hydrodynamic for a range of configurations (floater /turbine)

Spar Buoy

Semi-Submersible

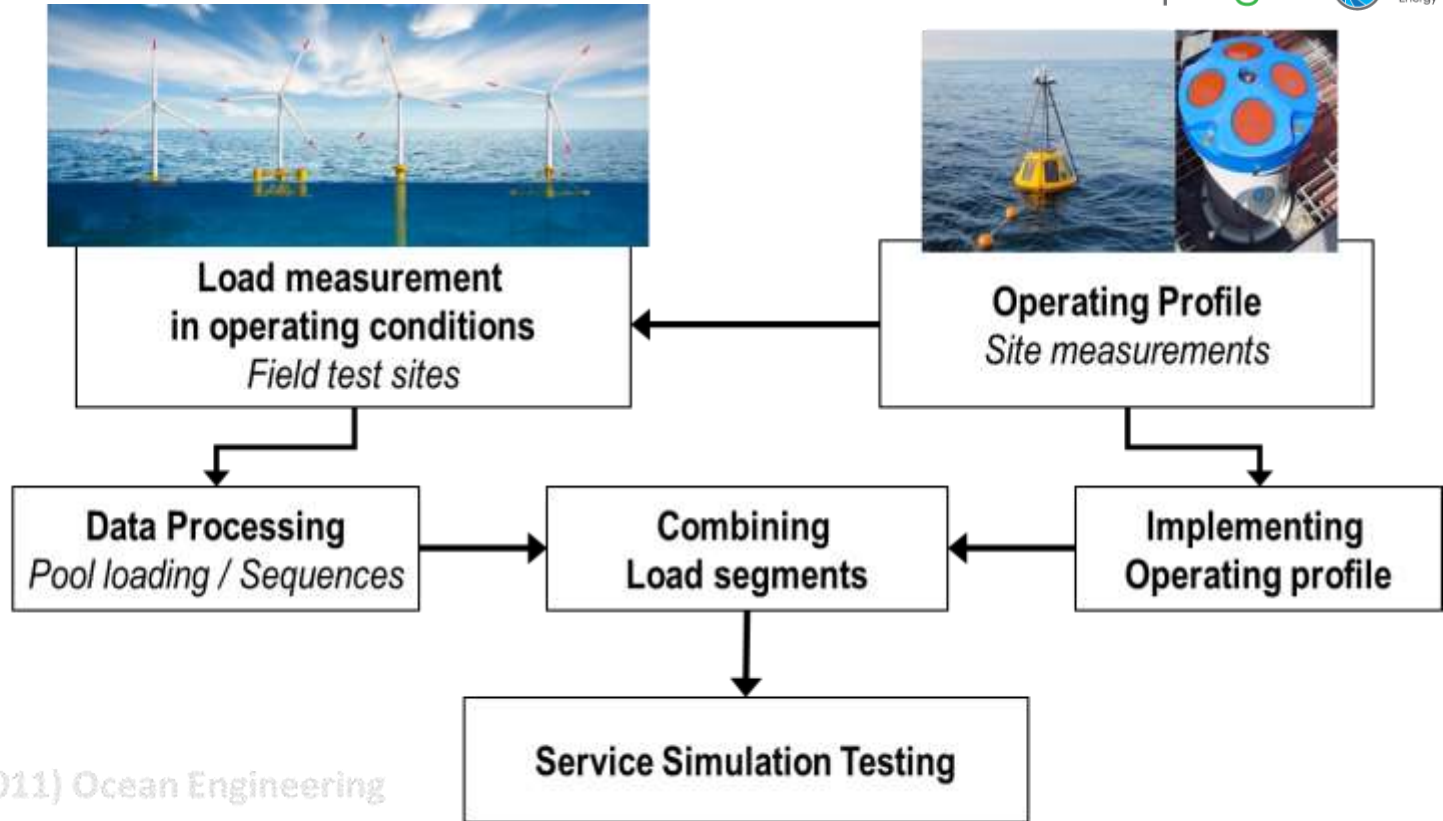
TLP



Load Case	v [m·s ⁻¹]	H_s [m]	T_p [s]	γ
Below Rated	8	6	10	2.87
Rated	11.4	6	10	2.87
Above Rated	18	6	10	2.87
Extreme	50	12	17	1.11

Load Case	Mean Load Reduction		Max. Load Reduction	
	Absolute [MN]	Relative [%]	Absolute [MN]	Relative [%]
Spar				
Below Rated	0.1	11%	0.2	11%
Rated	0.1	10%	0.3	15%
Above Rated	0.1	11%	0.2	12%
Extreme	0.1	13%	0.4	18%
Semi-Sub				
Below Rated	0.2	16%	0.4	21%
Rated	0.2	14%	0.4	15%
Above Rated	0.2	17%	0.4	19%
Extreme	0.1	9%	0.6	17%

Service simulation testing



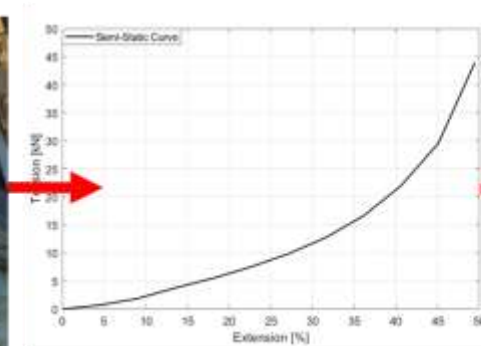
Combined Physical & Numerical Modelling

Advanced Coupled Hydrodynamic modelling for mooring and cable design.
Determine / iterate Ultimate Limit State and Fatigue Limit State

Physical testing of novel mooring components



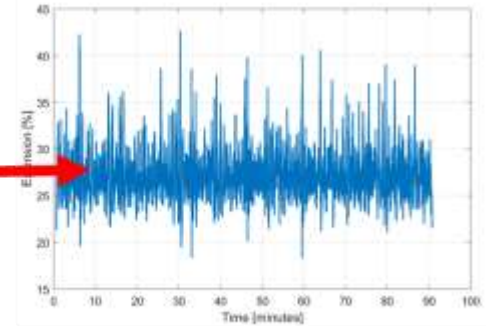
Measured Load-Extension Curve



Numerical Model

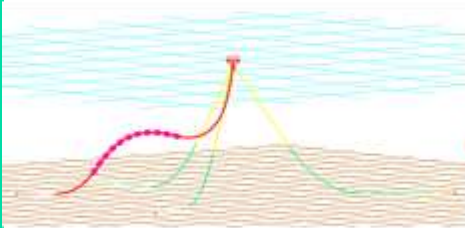


Time-Series of Extension/Tension



Cable modelling

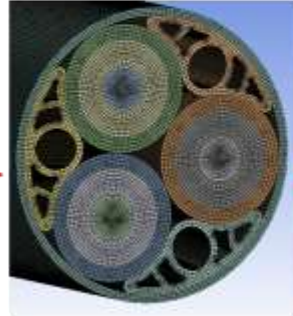
Global Model



Dynamic simulation

Interaction between environment and entire cable

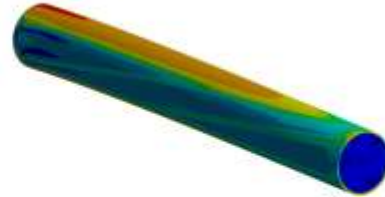
Local model 2D



Cross-sectional analysis

Cable properties

3D Stress analysis



Advanced computational analysis

Cable properties

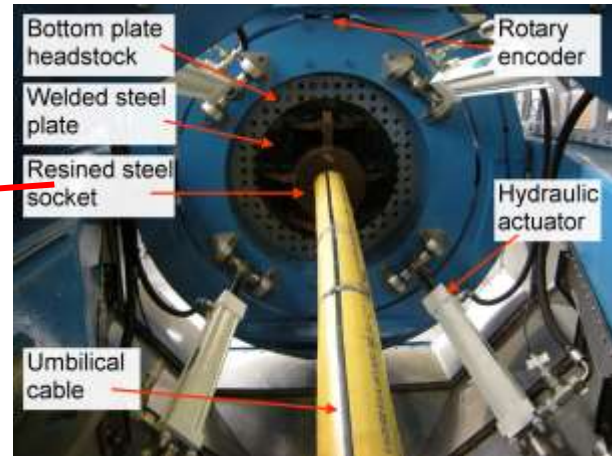
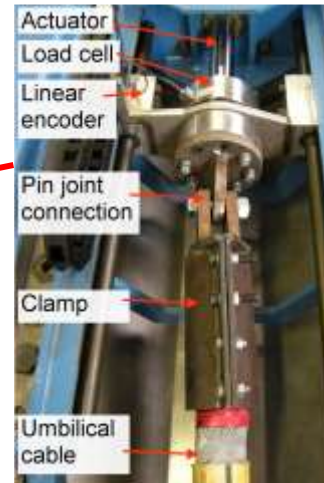
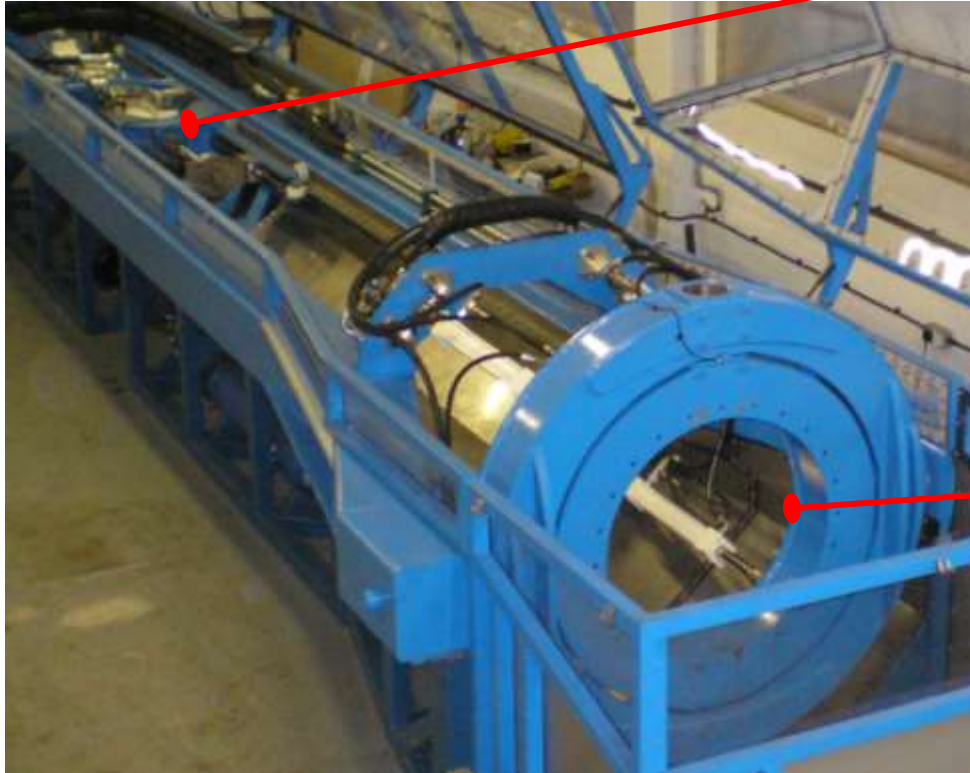
Physical testing



Cable testing

Electrical testing
Mechanical testing

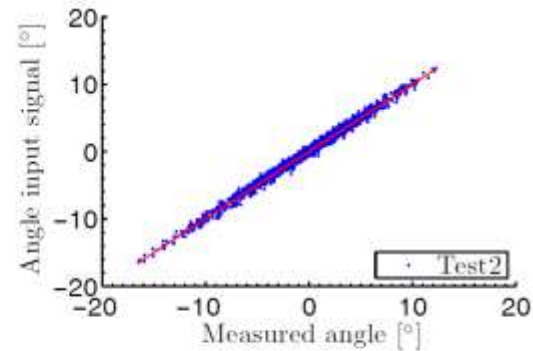
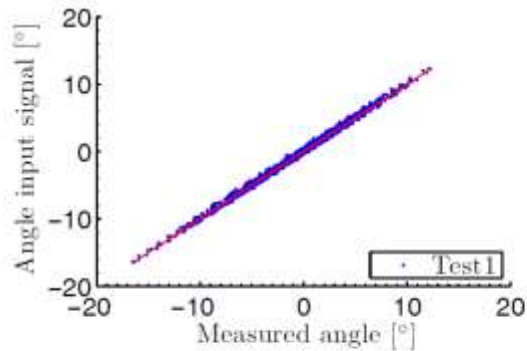
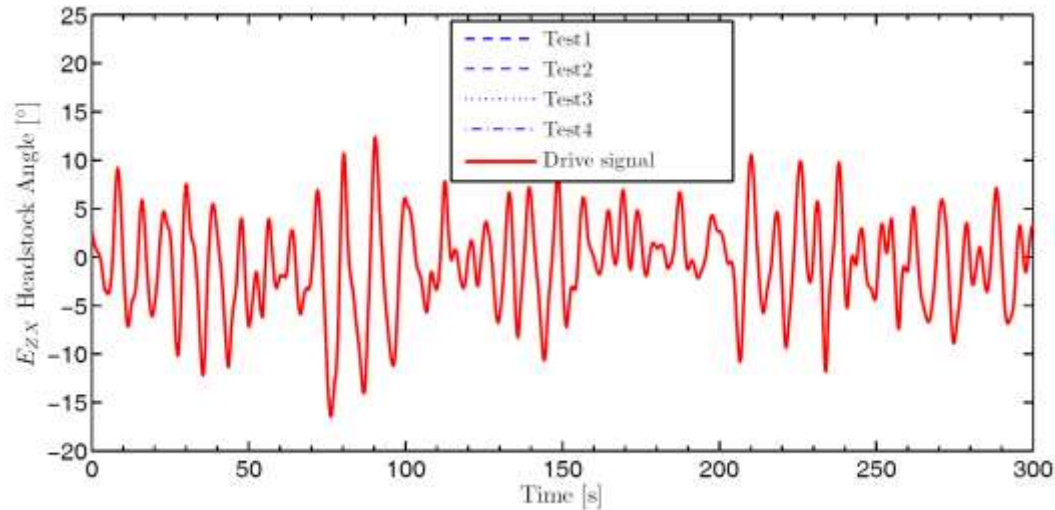
Cable Testing



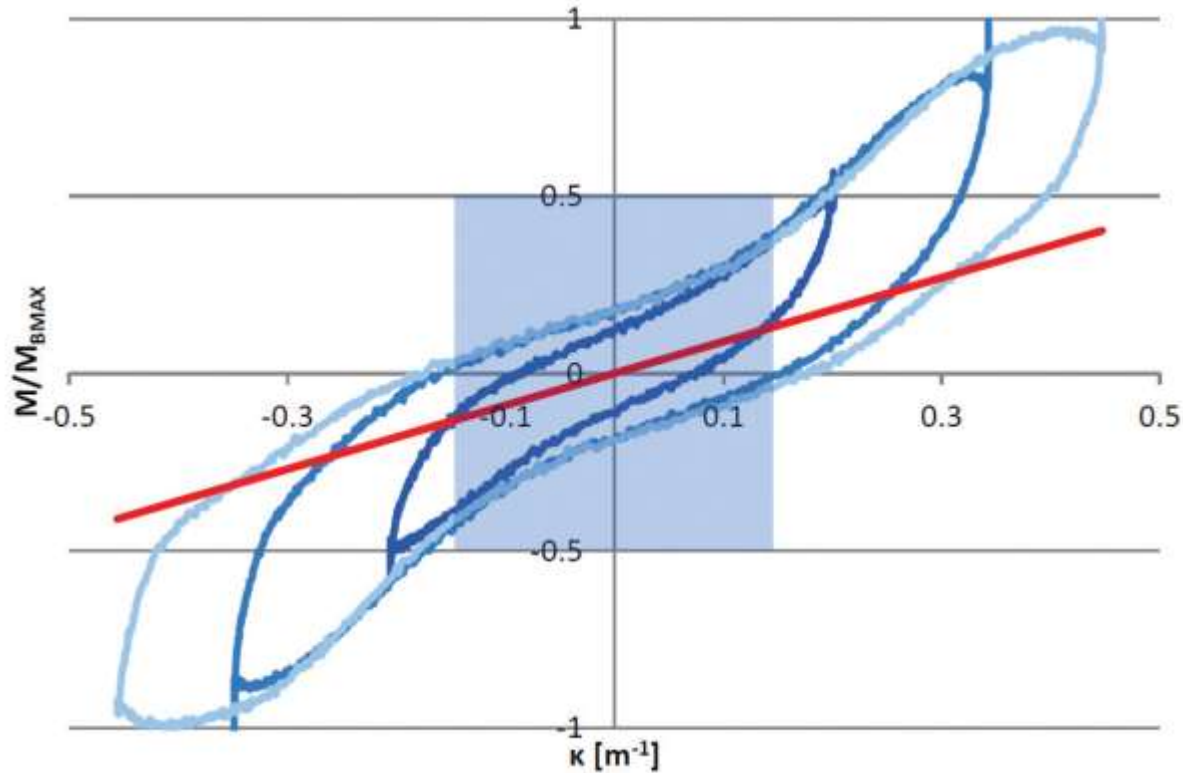
Cable Testing



Cable Testing



Cable Testing



Cable & bend restrictor testing

FAST-Orcaflex Model

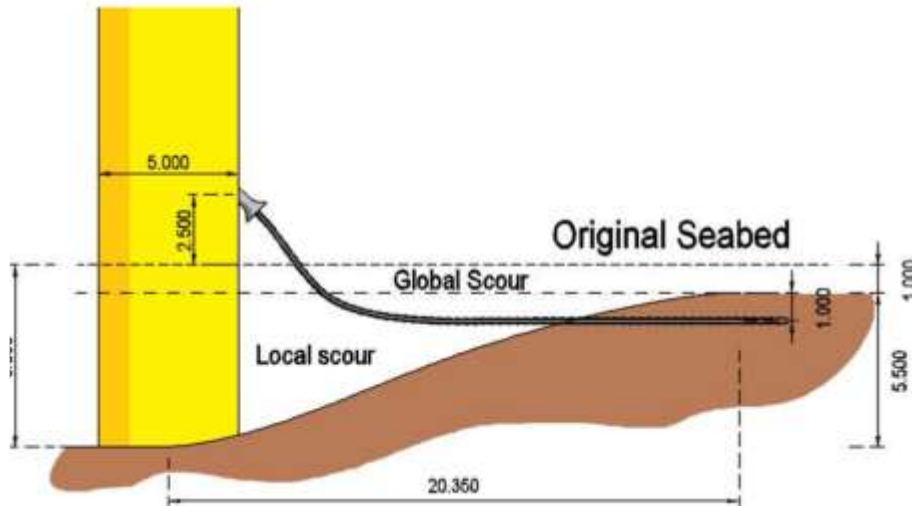
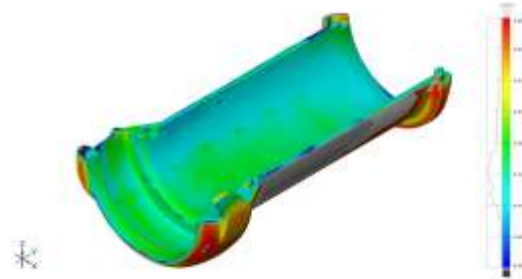


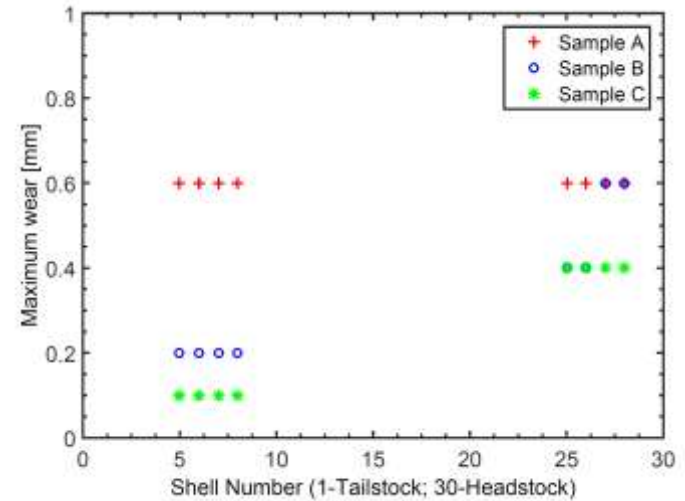
Table 3: Maximum load results between monopile/J-tube and CPS

CPS	Shear F_{max} [kN]	Axial F_{max} [kN]	Bending M_{max} [kN.m]
CP137-333	15.61	11.58	12.35

Cable & bend restrictor testing



Thies et al. 2016



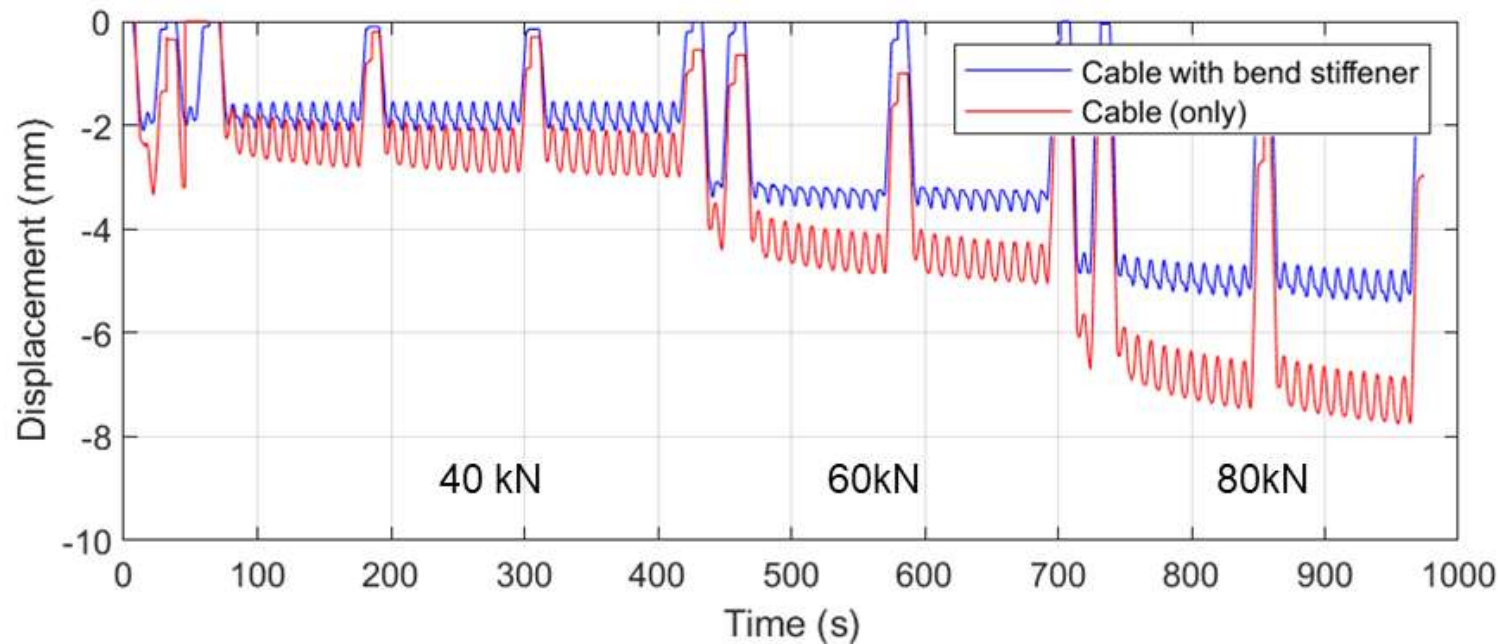
Cable & bend restrictor testing



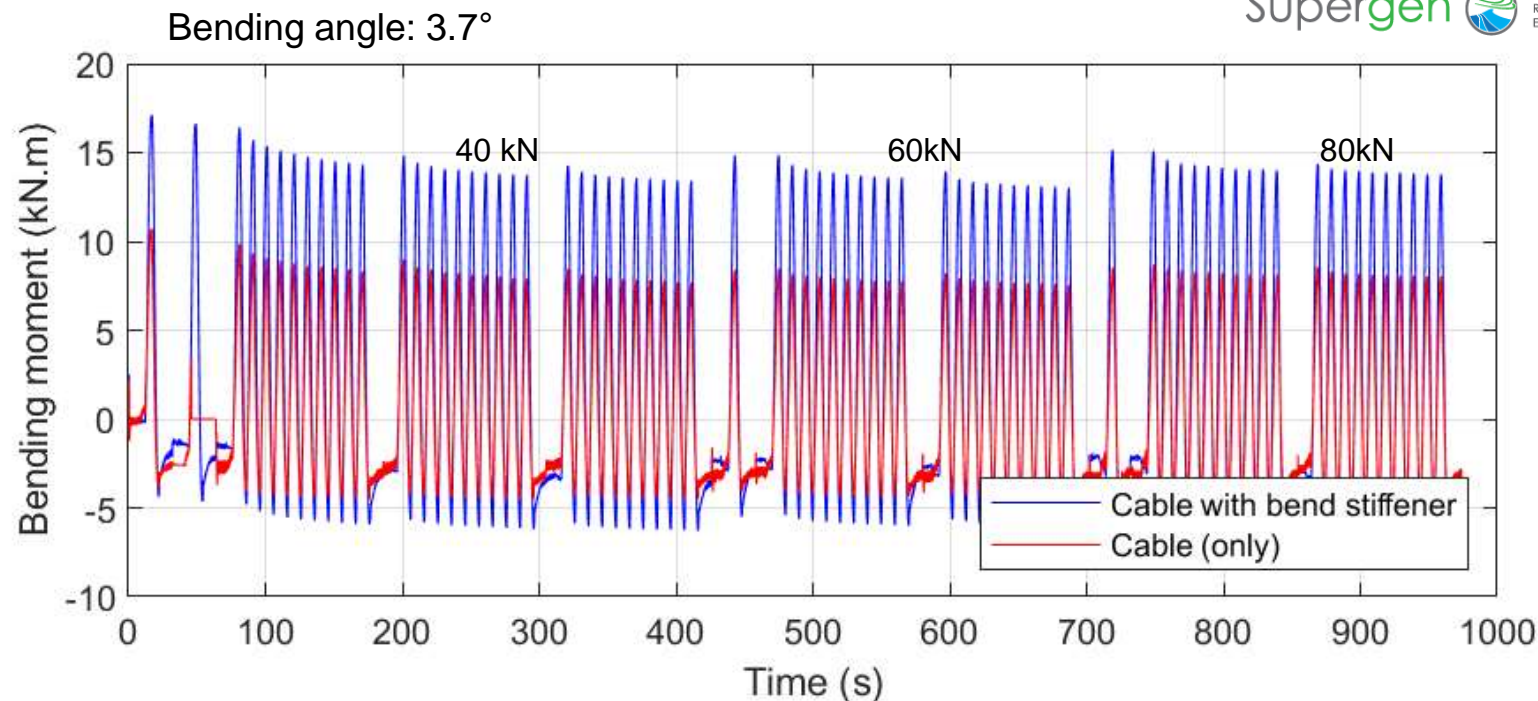
Cable & Bend stiffener testing



Cable & Bend stiffener testing



Cable & Bend stiffener testing



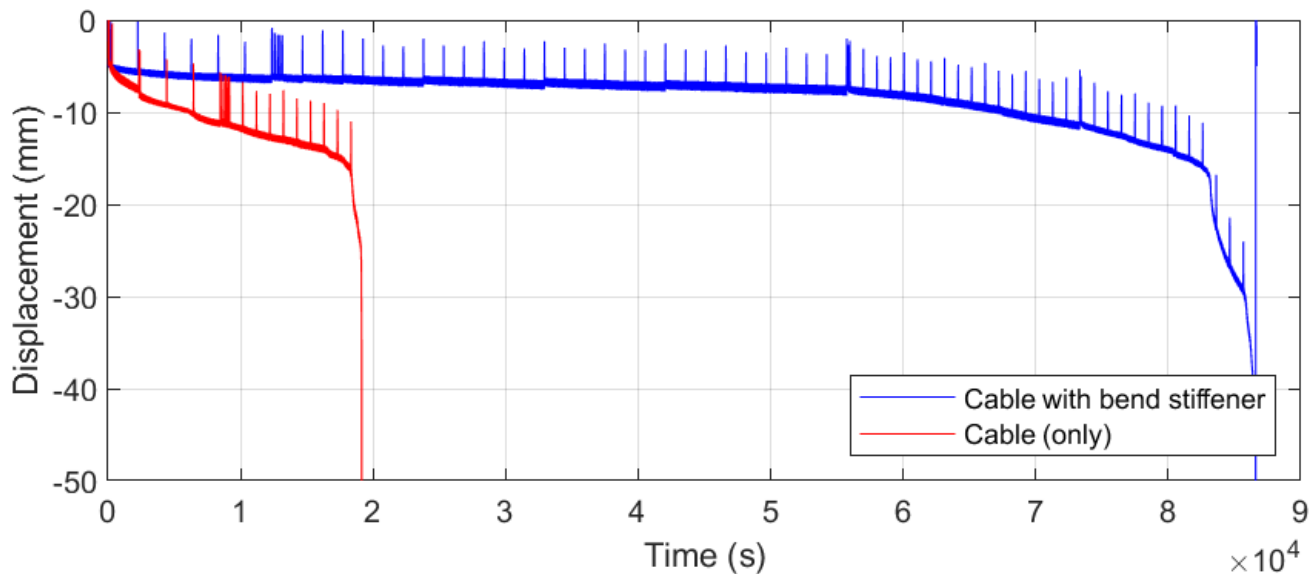
Cable & Bend stiffener testing

Force (kN)	Maximum bending moment (kN.m)			
	Cable (only)		Cable with bend stiffener	
	1st cycle	Last cycle	1st cycle	Last cycle
40	10.7	7.68	16.9	13.4
60	8.40	7.57	14.9	13.0
80	8.53	8.03	15.2	13.8



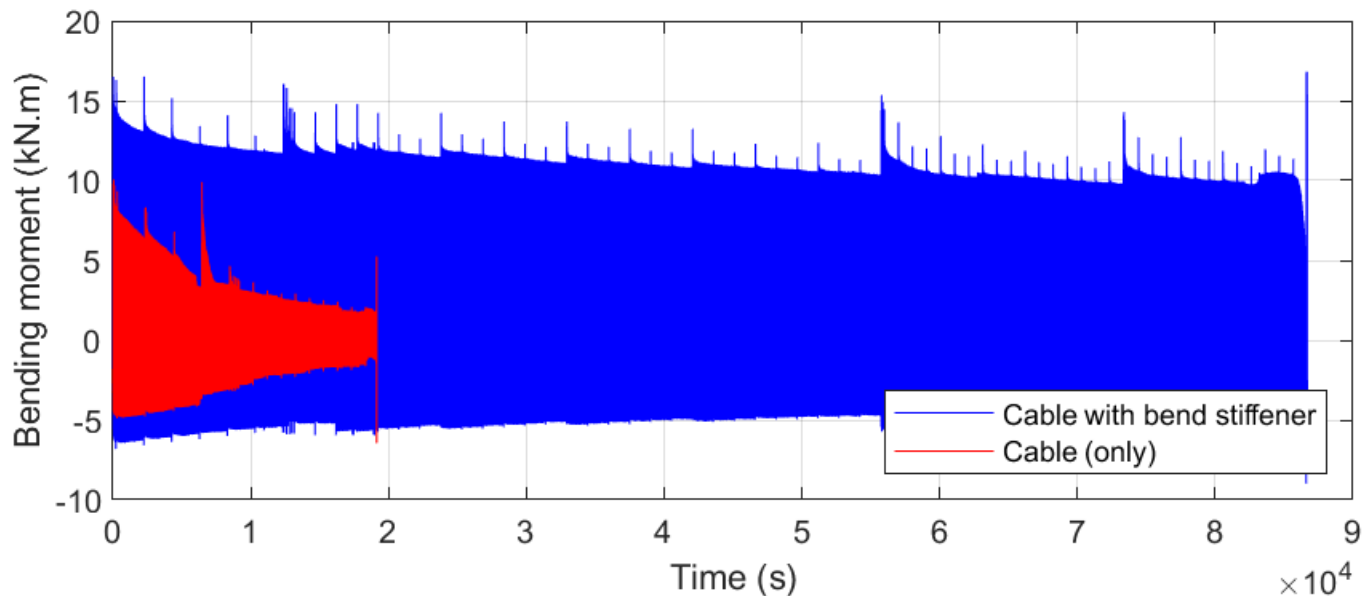
Cable & Bend stiffener testing

Fatigue Testing – Tension = 80kN; Angle = 4°



Cable & Bend stiffener testing

Fatigue Testing – Tension = 80kN; Angle = 4°



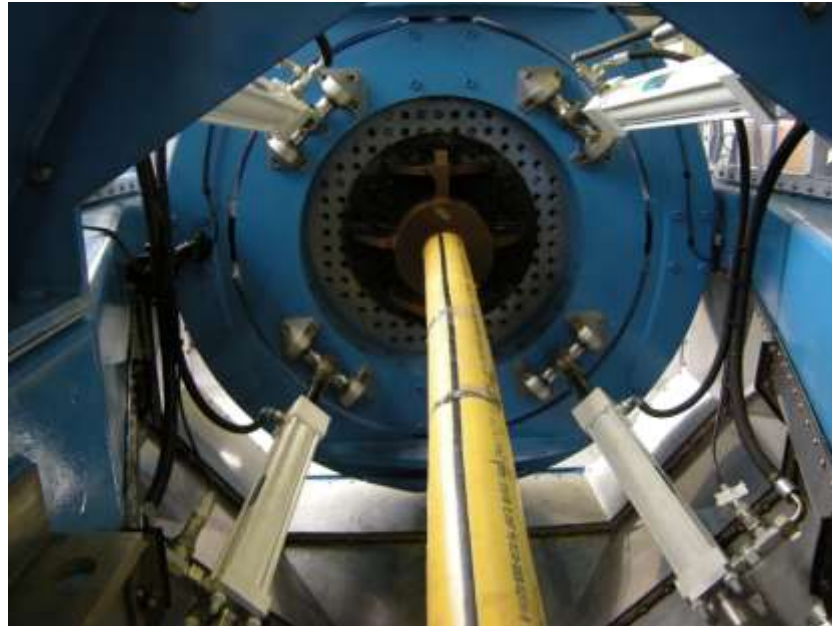
Discussion & summary

- Dynamic cable testing serves multiple purposes
 - Cable properties
 - Cable failure modes
 - Cable interaction with ancillaries
 - Fatigue testing
- Testing for new applications
- Allows to quantify cable endurance



Thank you for your attention

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www.supergen-ore.net

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