Risk Analysis Applied to Scour Dynamical Protection Systems for Offshore Foundations Optimisation

Risk Analysis and Probabilities of Failure in Offshore Monopile Foundations

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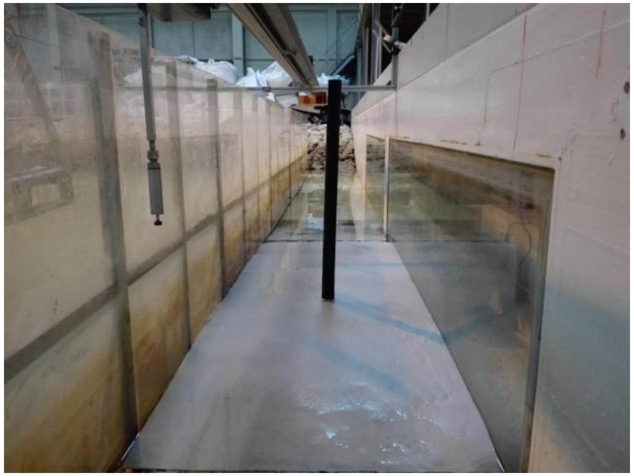
Introduction

The support structure can represent about 25-34% of the total cost;

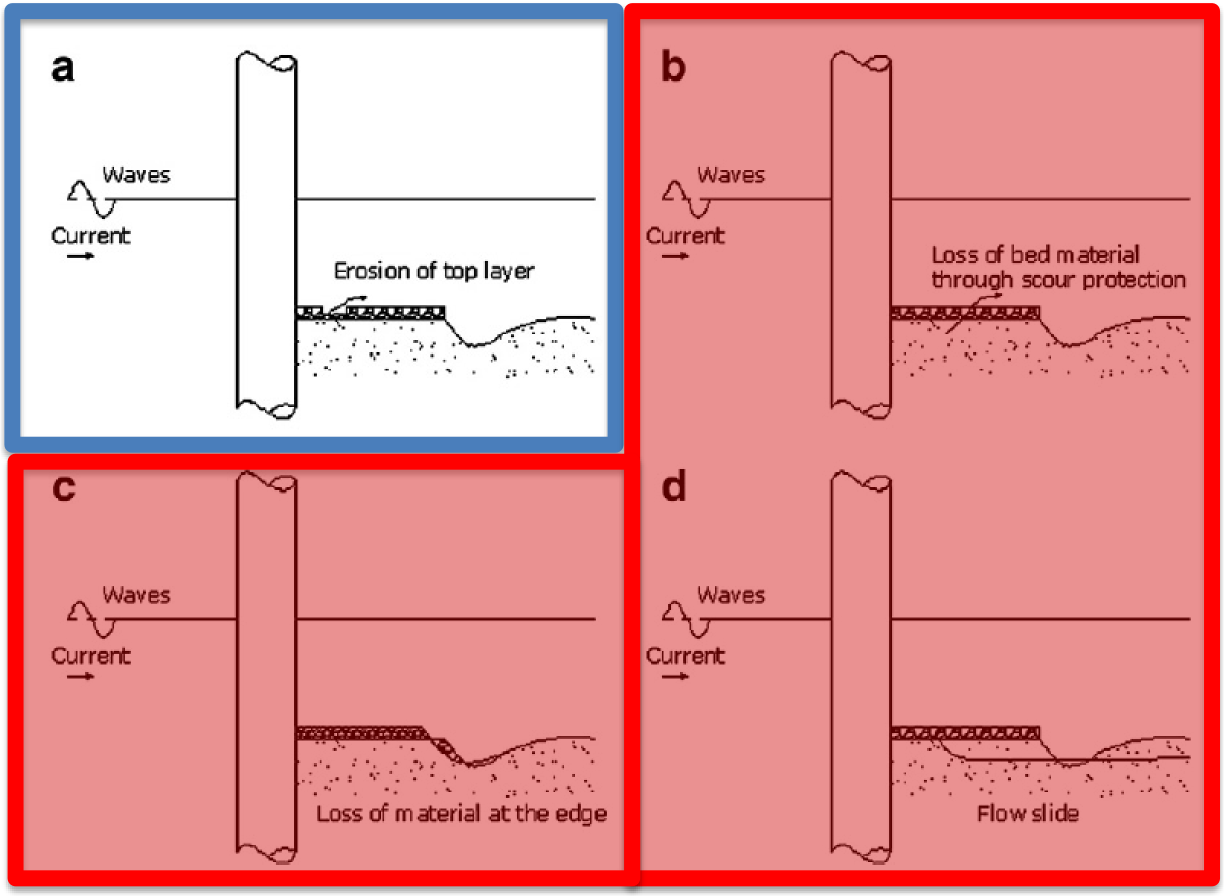
Scroby Sands (80 turbines);

London Array (175 turbines);

Second year workout



Failure Modes of Scour Protections



a) Erosion of the top layer

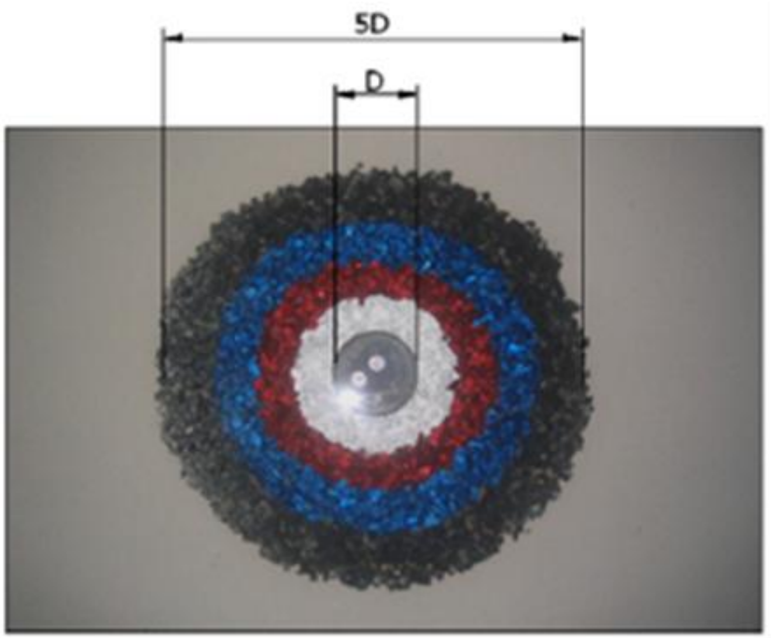
b) Loss of subsoil through the scour protection

c) Edge scour

d) Flow slide

Probabilities of Failure in Scour Protections - Database

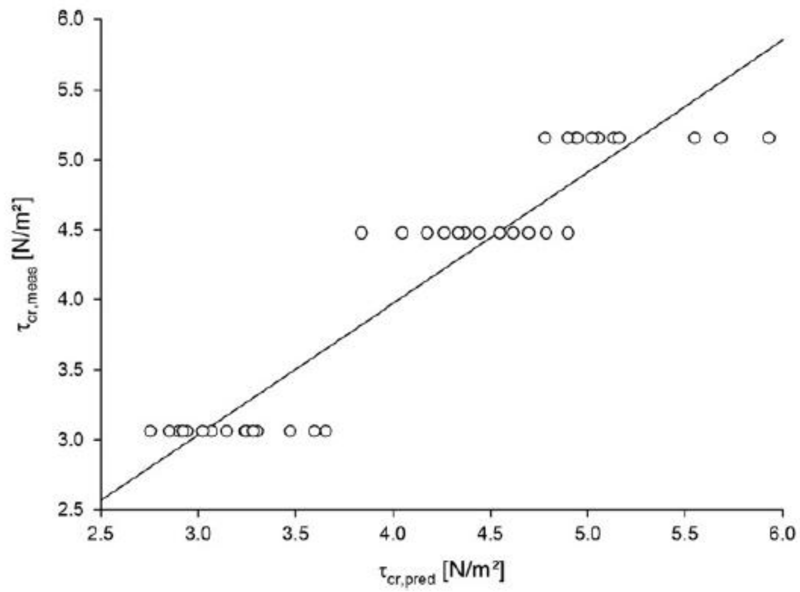
“*how to obtain the probability of failure of a scour protection, under waves and currents combined?*”



$$\tau_S = 83 + 3.569 \times \tau_c + 0.765 \times \tau_w$$

Probabilities of Failure in Scour Protections - Database

"how to obtain the probability of failure of a scour protection, under waves and currents combined?"



$$\tau_S = 83 + 3.569 \times \tau_c + 0.765 \times \tau_w$$

Probabilities of Failure in Scour Protections – Failure Criterion

Loads – Acting bed shear stress – de Vos (2008)

$$\tau_S = 83 + 3.569 \times \tau_c + 0.765 \times \tau_w$$

Resistance – Threshold of motion criteria – Shields (1936)

$$\tau_r = \theta_{cr} \times \rho_w \times g \times (s-1) \times 0.25 \times \log\left(\frac{D_{85}}{D_{15}}\right) = \theta_{cr} \times \rho_w \times g \times (s-1) \times D_{67.5}$$

"The scour protection fails if the acting shear stress overcomes the resistant shear stress for which the protection was designed, i.e. if (τ_S) > (τ_r)."

Probabilities of Failure in Scour Protections – Reliability Problem

Limit state function g(X) = Resistance-Loads

$$g(X) = \tau_r - \tau_s$$

$$SF = \frac{\tau_r}{\tau_s}$$

Only applicable to the failure mode: Erosion of the Top Layer

Input Parameter	µ	s	Prob. density function
Water depth (d)	20 m	0.5 m	Normal dist.
Current velocity (U_c)	1.5 m/s	0.7 m/s	Normal dist.
Significant wave height (H_s)	6.5 m	0.5 m	Normal dist.
Stones density (ρ_s)	2650 kg/m3	-	Constant
Water density (ρ_w)	1025 kg/m3	-	Constant
Shields Parameter (θ)	0.035	-	Constant
Sediment Uniformity Parameter ($\sigma = D_{85}/D_{15}$)	2.5	-	Constant

Methodology (summary)

1 - Determine the random variables that rule scour phenomena and describe them by their probability density function

2 - Define the probabilistic model for the scour occurrence

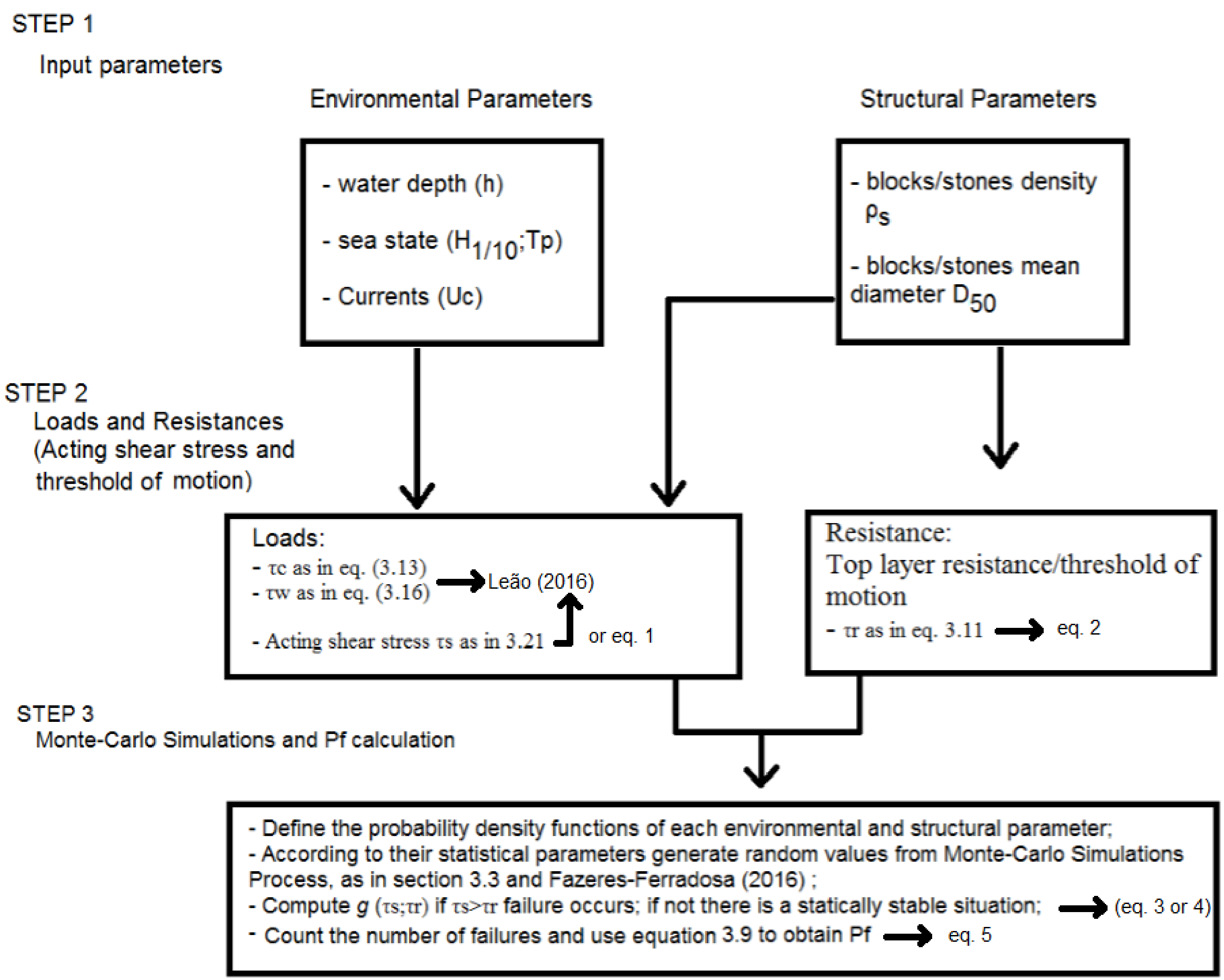
3 - Use Monte-Carlo Method to simulate the random variables

4 – Define the failure criteria, using the performance function g(x)

5 – Calculate g(x) for each pair of simulated random variables and obtain P_f

6 – P_f gives a measure of uncertainty related to a global safety factor

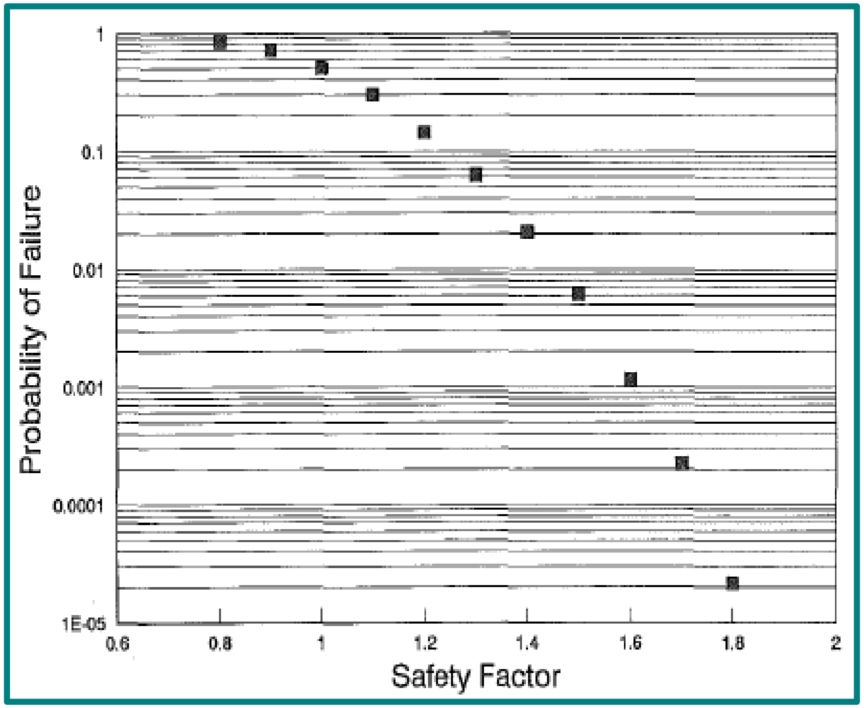
Methodology (summary)



$$P_f = \frac{n^{o}(g<0)}{N}$$

Some Results and Discussion

SF (-)	D_{50} (m)	P_f [0;1]
0.80	0.26	0.98
0.90	0.32	0.79
1.00	0.39	0.52
1.10	0.47	0.29
1.20	0.57	0.14
1.30	0.68	0.064
1.40	0.81	0.025
1.50	0.96	0.0088



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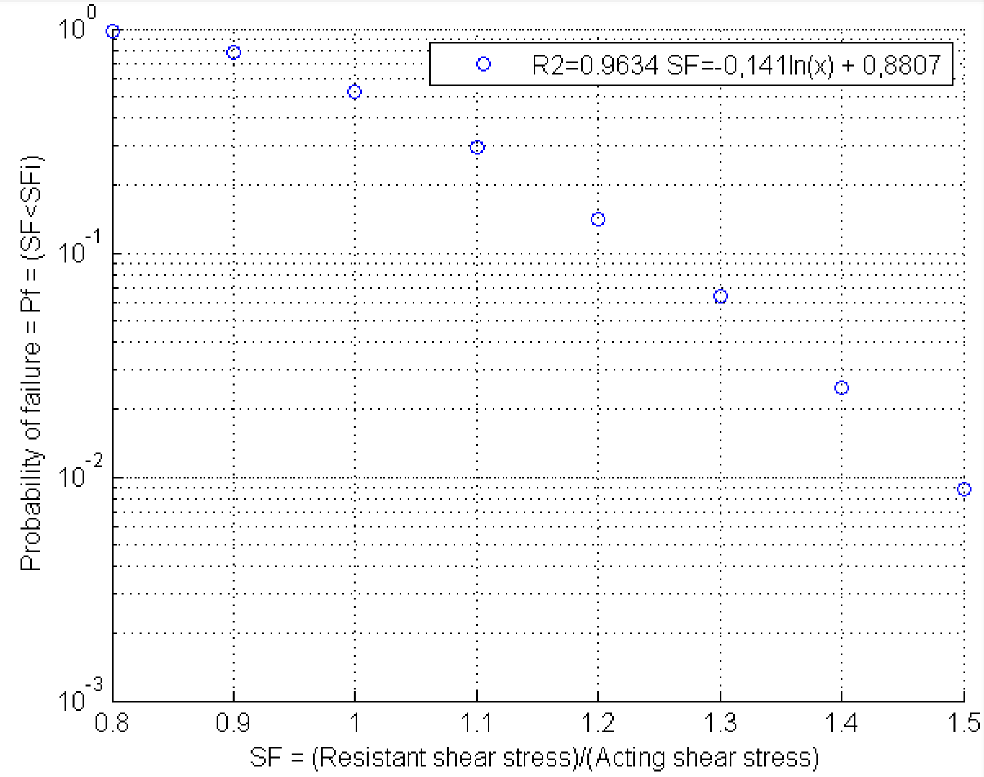

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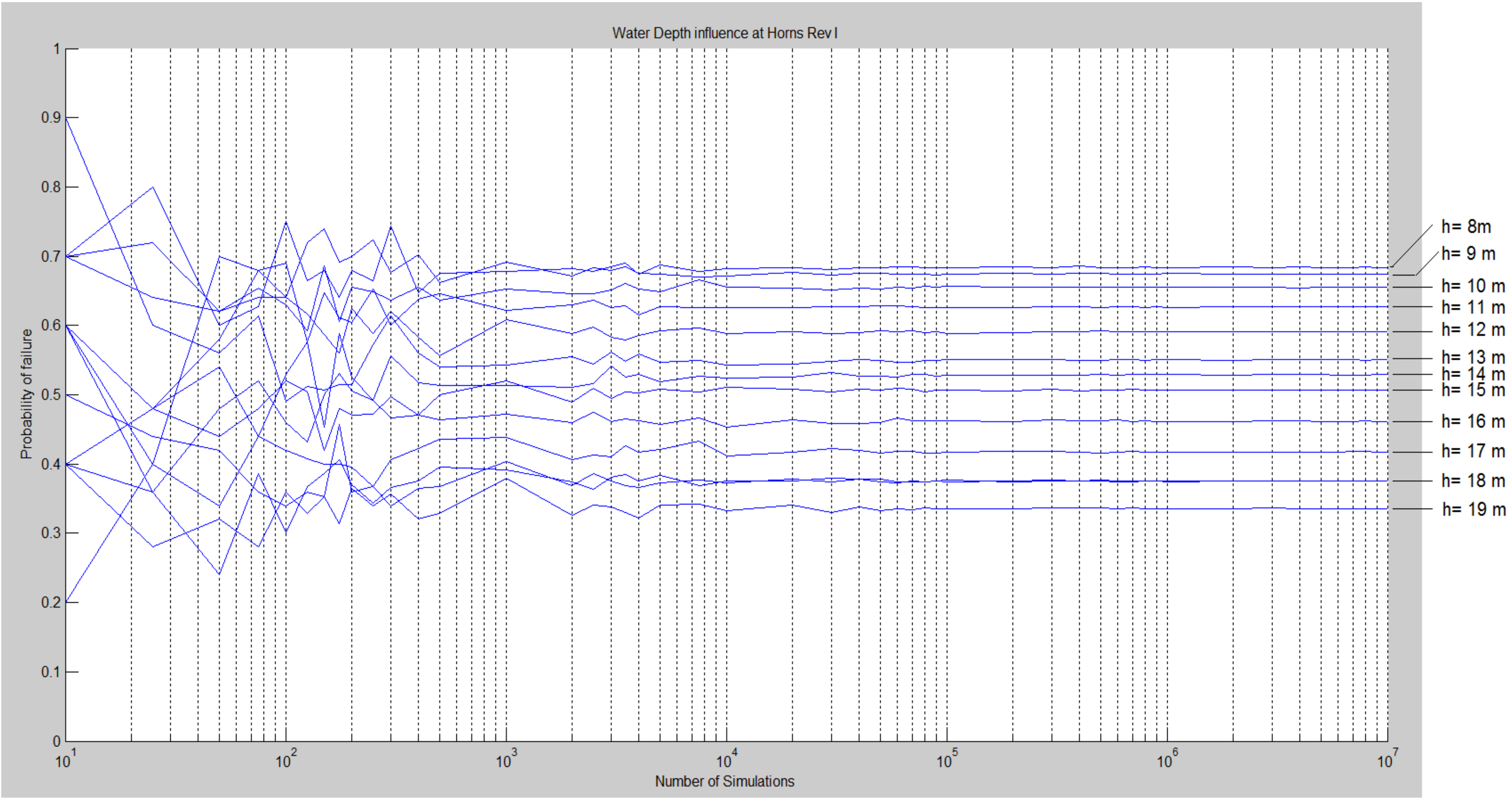

2015 Objectives – 2016 Accomplishments

- Dynamically stable scour protections:
  - Physical modelling – scour tests – continuation of 2015;
  - Data sampling and statistical characterization of the random basic variables – avoid fitting and seek for simulation models;
  - Performance function evaluation (limit state function);
  - Complex loads combinations, particularly with waves and currents combined.
- Risk and reliability methods for scour protections:
  - Statistical model development;
  - Evaluation of the reliability techniques applicable for the design performance function;
  - Development of guidelines for the new design methodology;
  - Validation with a case study – Horns Rev 1

Conclusions and Future Research

The methodology to obtain Pf for static scour protections was successfully achieved.

The implemented algorithm accurately represented the variables influence, but optimisations are needed:

- Consider the correlation between variables;
- Improve the random generation with field data incorporation;
- Assemble the joint probability functions.

A suitable failure criterion was found and incorporated into the reliability approach.

This criterion must be adapted to dynamic scour protections.

The present PhD research is now entering in its third phase, which is the physical modelling tasks for the reliability model validation and the risk analysis applied to Horns Rev 1.

References

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THANK YOU!