UNIVERSITÉ DE NANTES

IUML FR CNRS 3473

WORKSHOP "Challenges and Solutions for Improved Durability of Materials"

Interreg North-West Europe OPIN European Regional Development Fund

Monitoring and Modeling of the durability of Reinforced Concrete in marine environnement: state of the art and challenges

Pr. F. Schoefs

et al.

(E. Bastidas, Y. Lecieux, M. Torres, M. François, C. Lupi, D. Leduc, S. Bonnet, I. Othmen, C. Clerc, M. Oumouni, ...)

TRUST Group, GeM lab UMR CNRS GeM

CEO Sea and Littoral Research Institute

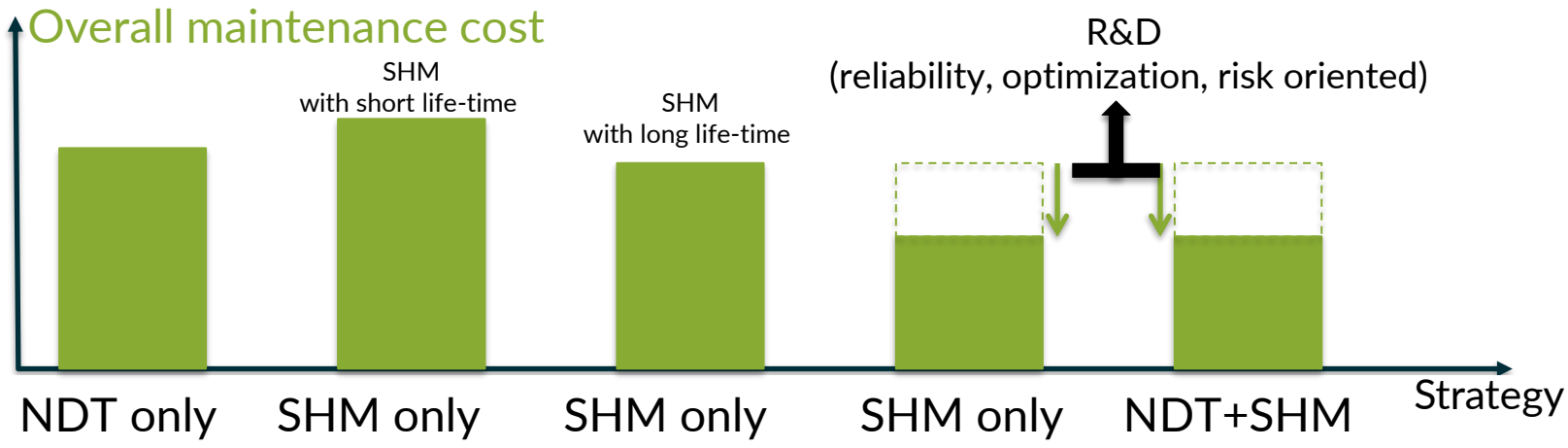
- Part 1 – Why monitoring?

High costs of maintenance in complex (marine) environment:

Key issues: logistic governs the costs and marine conditions governs the feasibility (storms)

- Increase quality control during manufacturing (traceability) >> NDT (intrusive for manufacturing process) or SHM (intrusive but used during operation too) >> added value to be quantify

- Optimize maintenance by selected the good maintenance time and action (preventive) >> added value of SHM



- Part 1 – Why monitoring?

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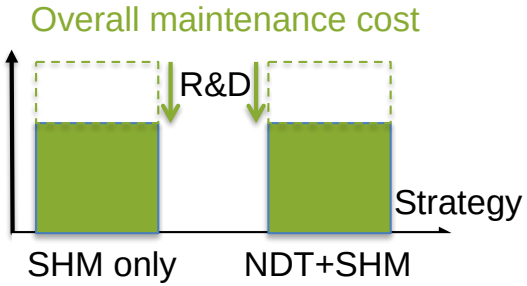
- Get a feedback for the next design (reported depreciation)

Quantify the added value of SHM (COST action 1402):

- Compute the benefit // NDT based maintenance

- Include **all the costs**: sensor, implementation, data processing (soft and hardware), maintenance (non infinite lifetime)

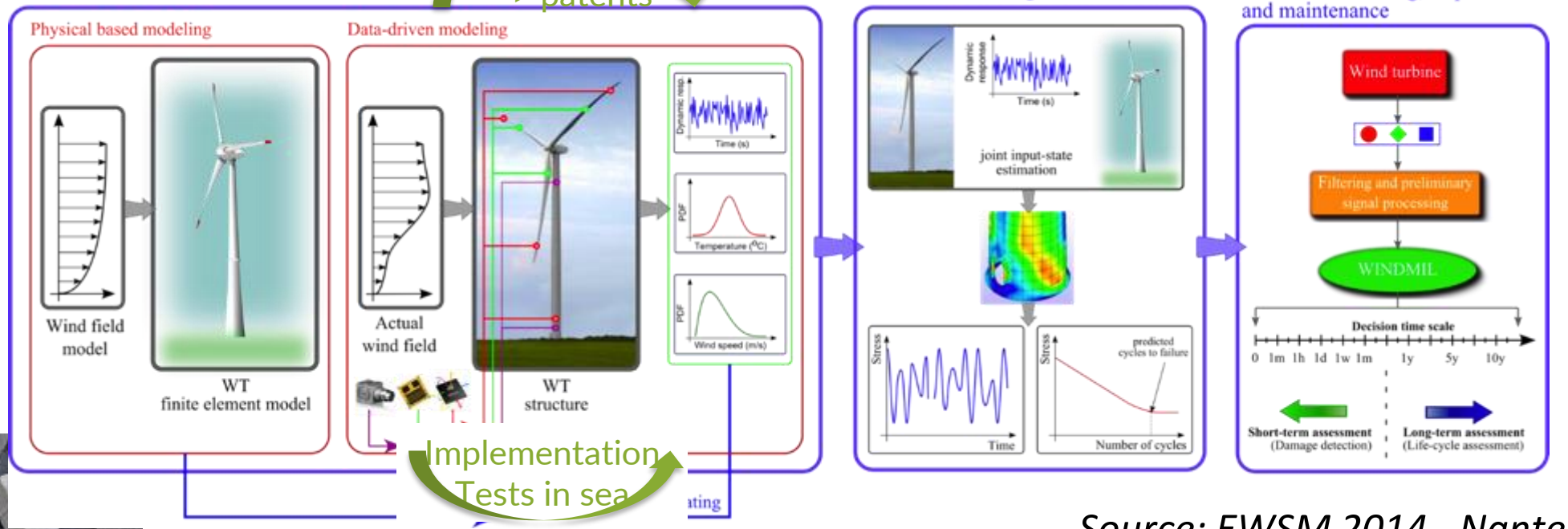
- Part 1 – Why monitoring?



Concrete: large uncertainties:

"lab-tests in the loop"

Concrete: multi-physics effects => patents



Implementation Tests in sea

Source: EWSM 2014 - Nantes

- Part 2 – Needs for a better design/maintenance

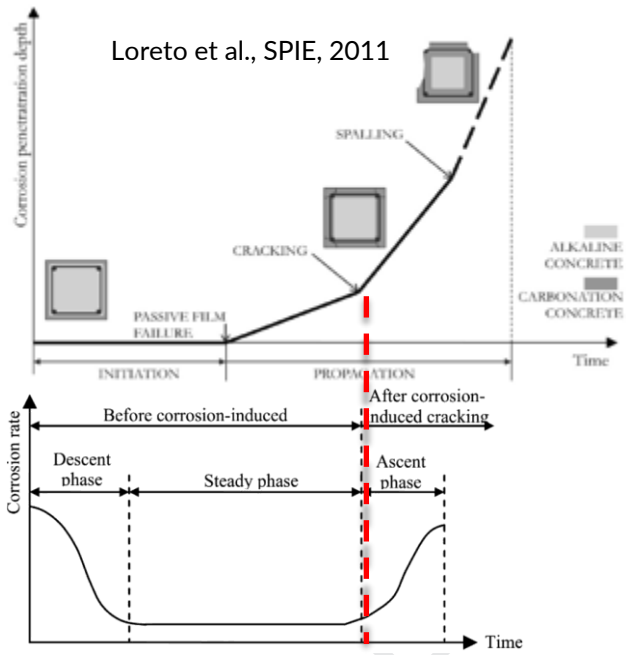
Concrete in the sea

Cyclic and dynamic loading
Fatigue (not usual for RC concrete design)

Effect of chlorides on pH

Damage

Cracks



. Tendency of the corrosion rate (Yuan et al., 2009)

- Part 3 – technologies and the needs

Feedback from O&G

1973 : the first offshore platform in Concret (DORIS) >> Ekofisk

1997 : the biggest (DORIS) >> Hibernia

BUT

➢ financial context (O&G <> MRE) >> over-sizing in O&G

➢ Only a few feedback:

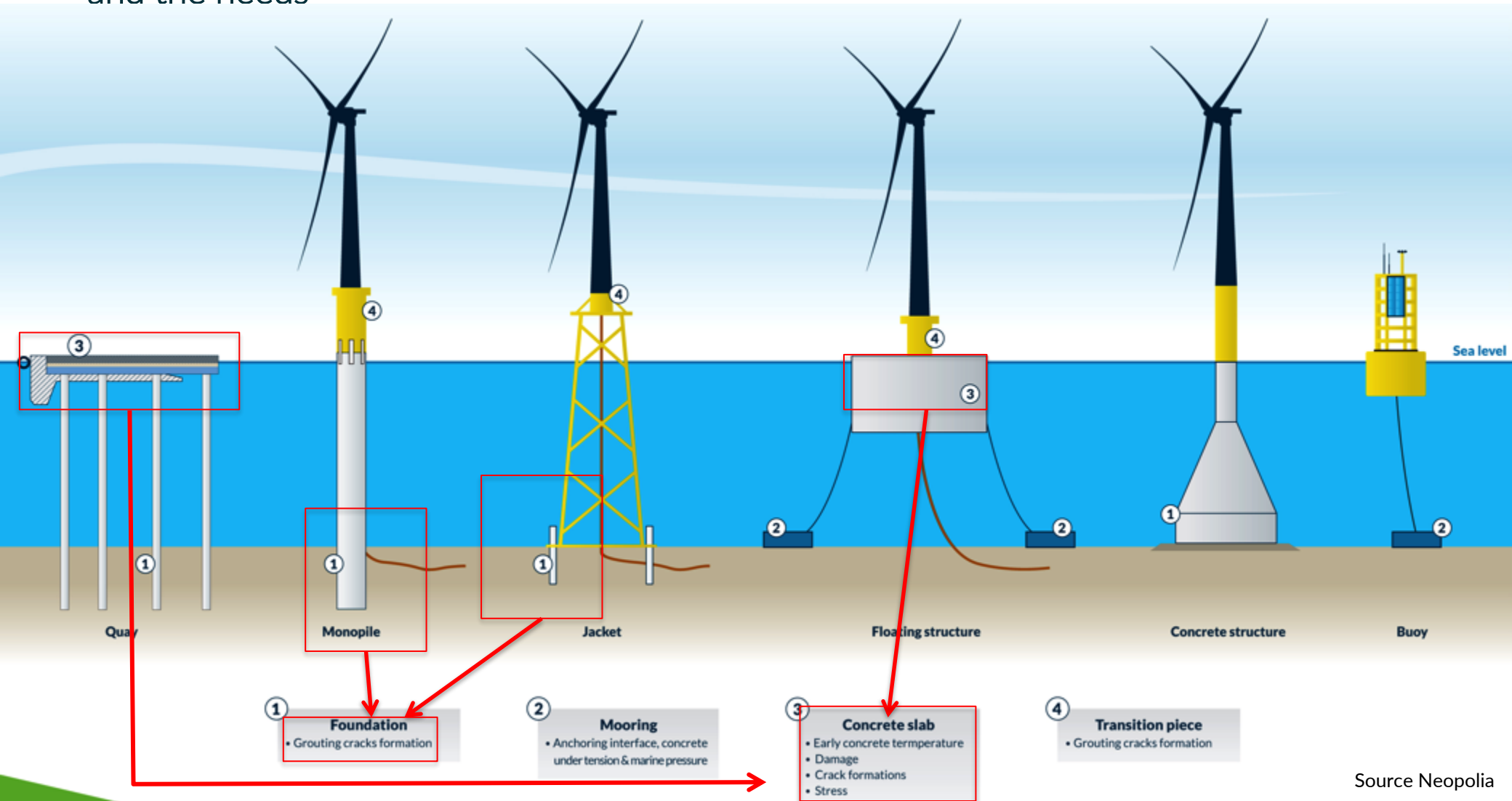
few dozen in various sites // 8000 steel structures

➢ New challenges: mooring and anchoring systems: still an issue

dynamic and cyclic loading on the anchoring system

- Part 4 – technologies and the needs

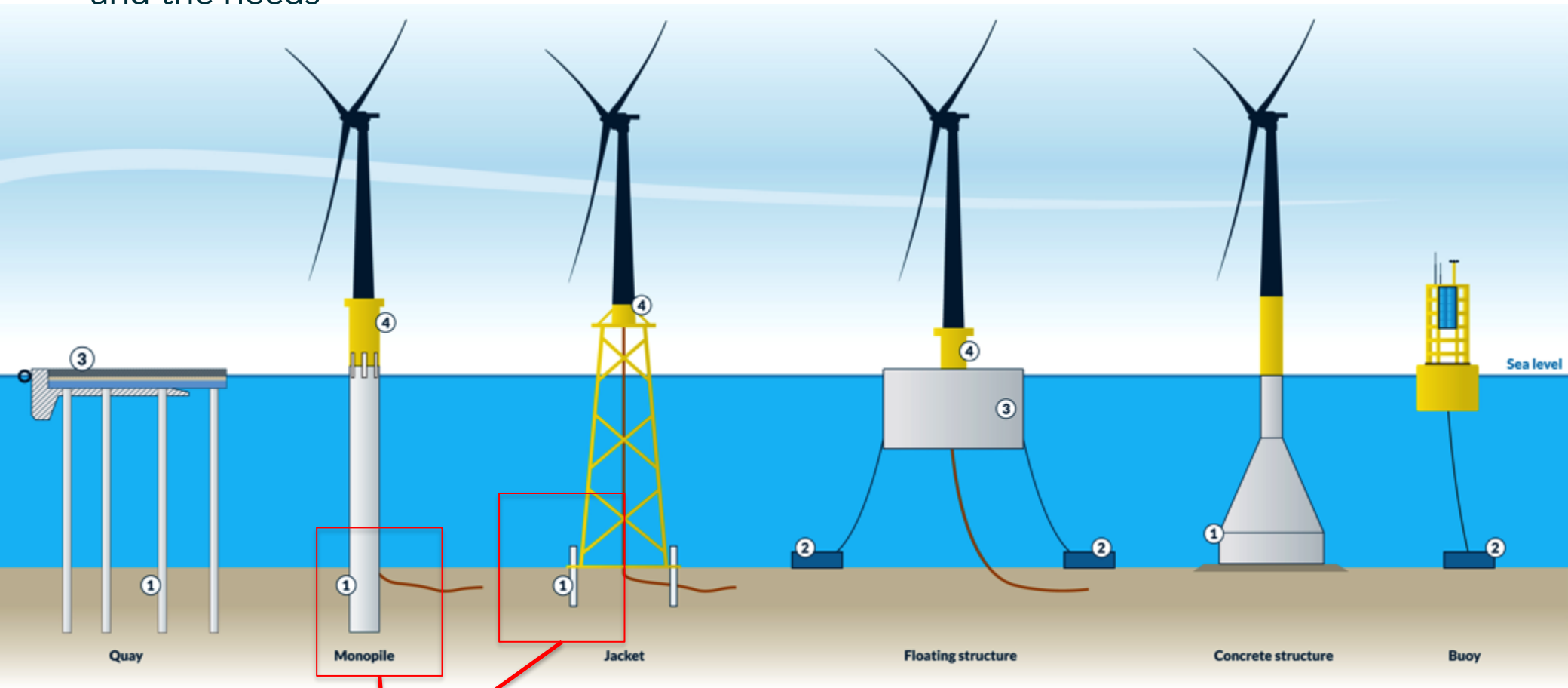
SHM is technology specific



Source Neopolia

- Part 3 – technologies and the needs

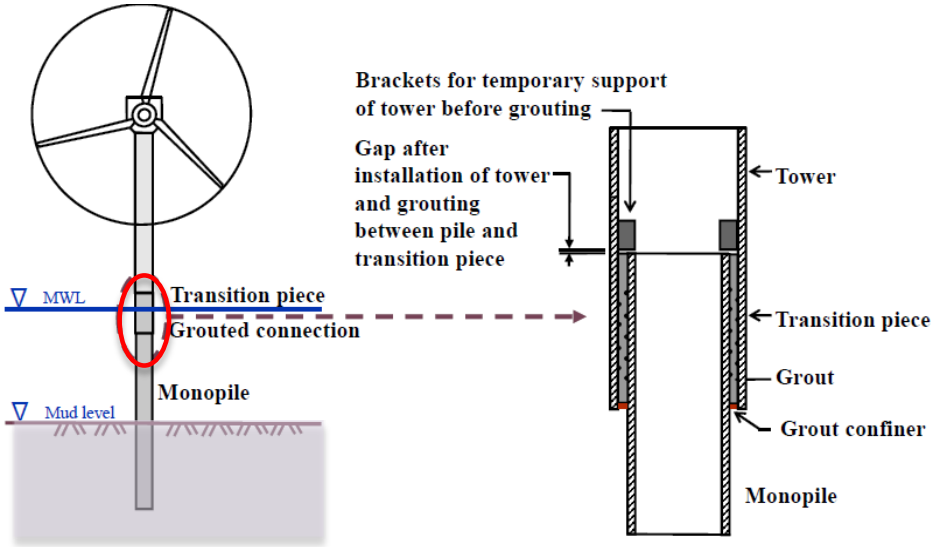
1. GROUTING



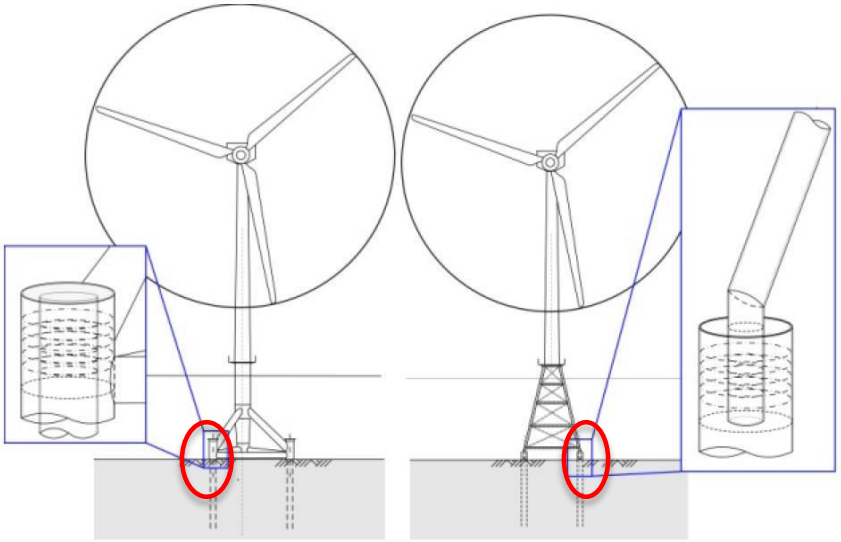
Source Neopolia

- Part 3 – technologies and the needs

GROUTING



OWT with a monopile substructure and detail of a grouted joint (DNV, 2014)



OWT with a tripod / jacket substructure and detail of a grouted joint (Schaumann et al., 2013)

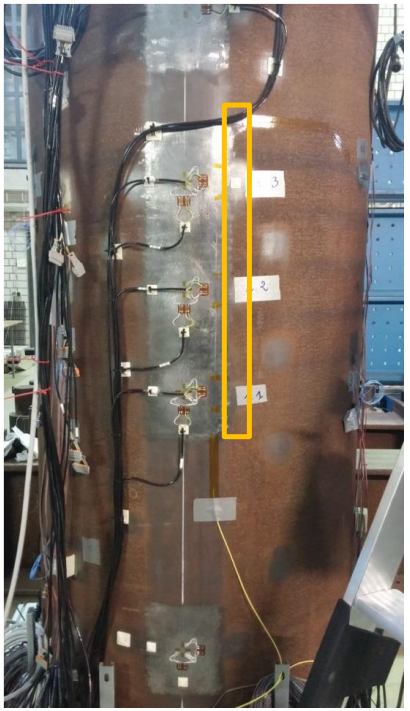
Significant sliding damages of grouted connections have been reported in 2009-2010

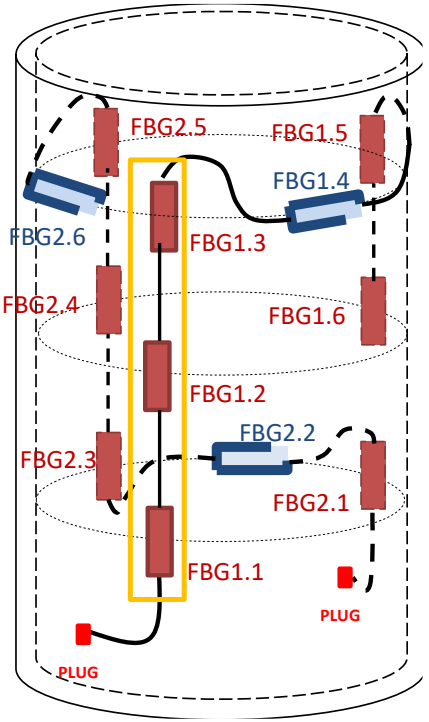
- **600 of the 988** monopile OWTs in the North Sea **60% !!**
- Cylindrical with shear keys + conical design recommended (DNVOS- J101 (2014), DNV-OS-C502 (2012), DNVGL-ST-0126 (2016))

- Part 3 – technologies and the needs

GROUTING

ITN OCEANET (UN, U Hannovre, Franhaufer, Whölfel)
+ SHM-OWT-Grout (UN, IFSTTAR, Keops, Charier)

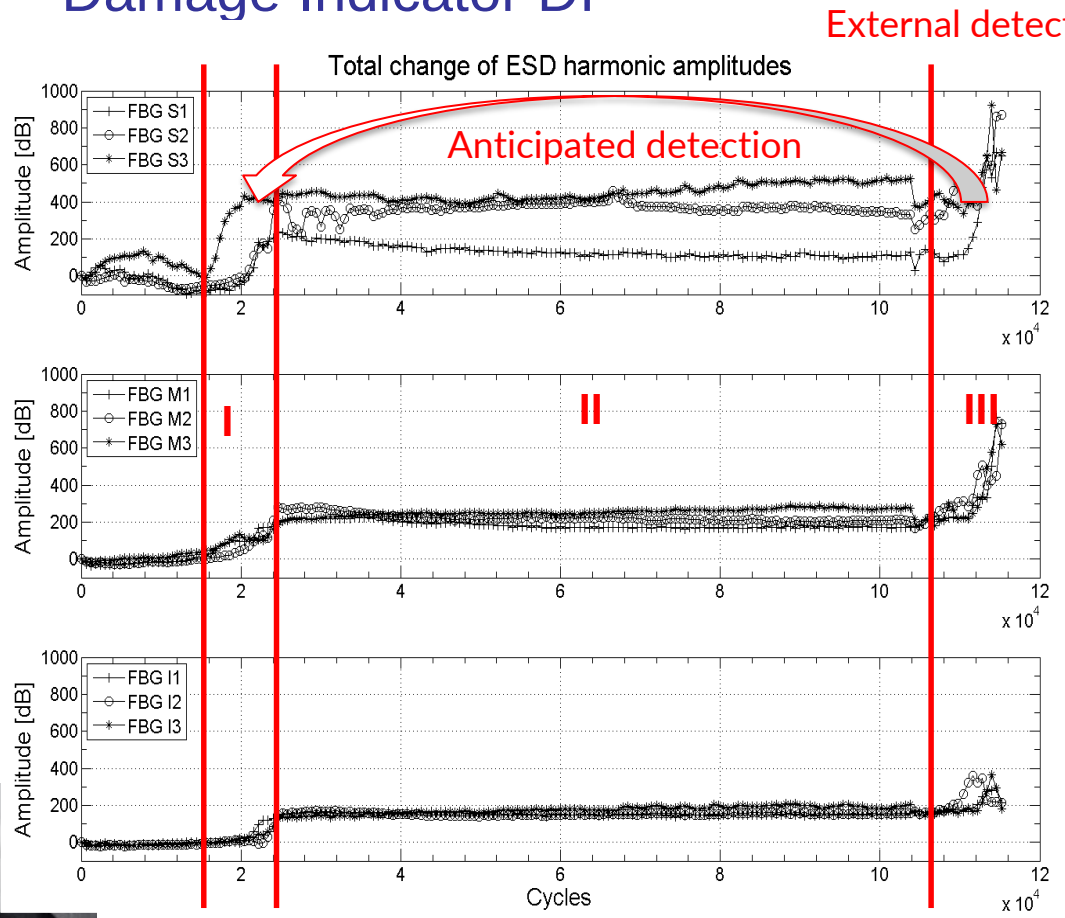




- Part 3 – technologies and the needs

GROUTING

Monitoring of the appearance of nonlinearities and selection of a Damage Indicator DI



→ Total change of subharmonics in the normalized ESD spectrum

$$DI = \sum_{j=1}^{N} (H_{j,damaged} - H_{j,healthy})$$

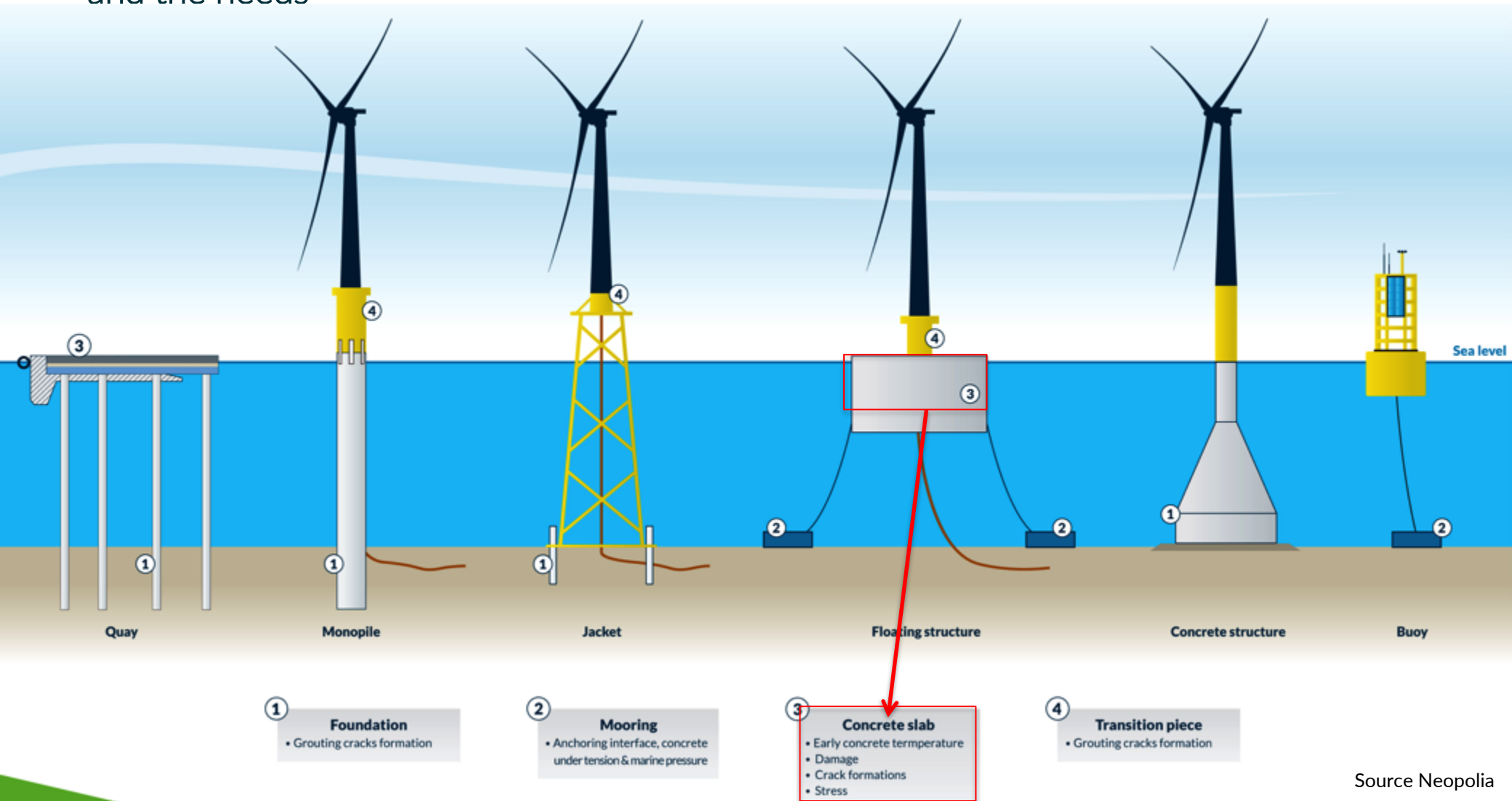
with H_j being the peak amplitude of the subharmonic j, and N the total number of subharmonics

→ **Cyclic creep curve**

Fraunhofer IWES

- Part 3 – technologies and the needs

2. Concrete Slab

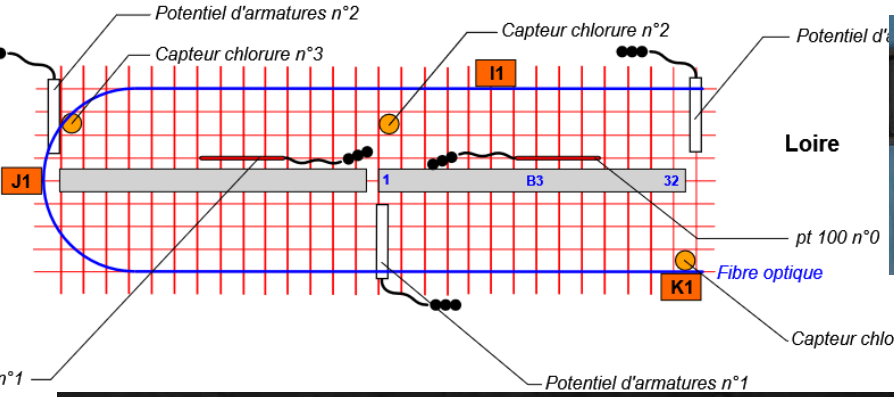


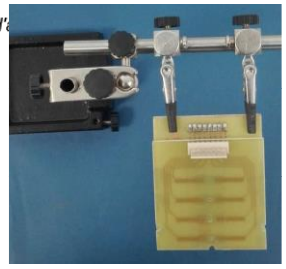
Source Neopolia

Part 3 – technologies and the needs

Damage and Chloride Ingress

Tests on site (monitoring)





Chlordetect. Université de Nantes

Accelerated hybrid tests

Chloride Ingress: chloride content at the rebar

Potential: initiation of corrosion

Time-scale factor: BN [Tra Bastidas, Schoefs 2016]

Reduce uncertainty in model prediction And in initiation of corrosion Ccrit

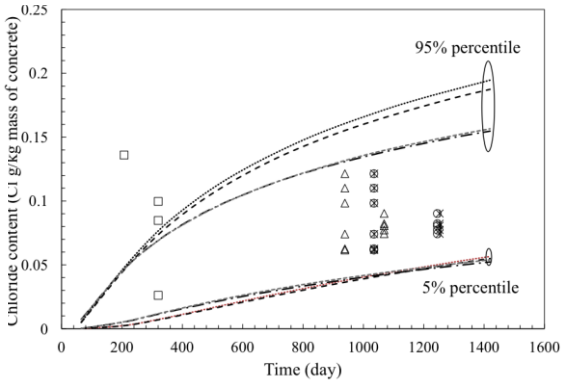


Figure 16 5% and 95 percentiles of chloride content at depth x=31.5mm

Part 4 – technologies and the needs

Damage and Chloride Ingress

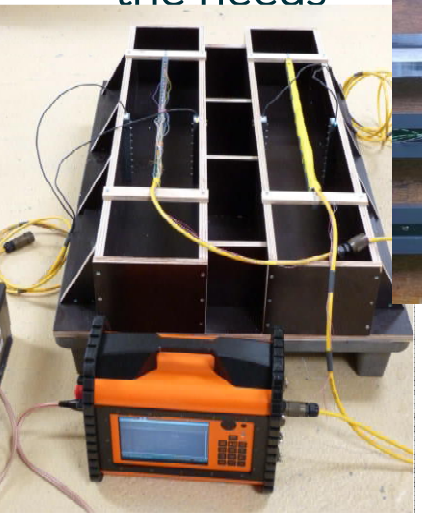
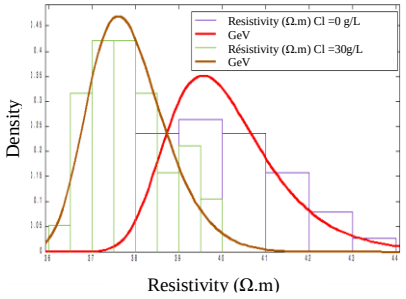
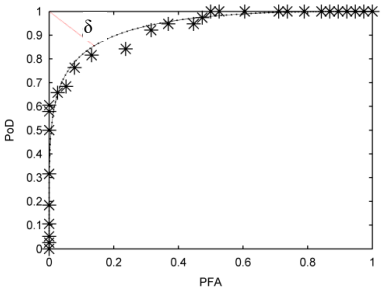


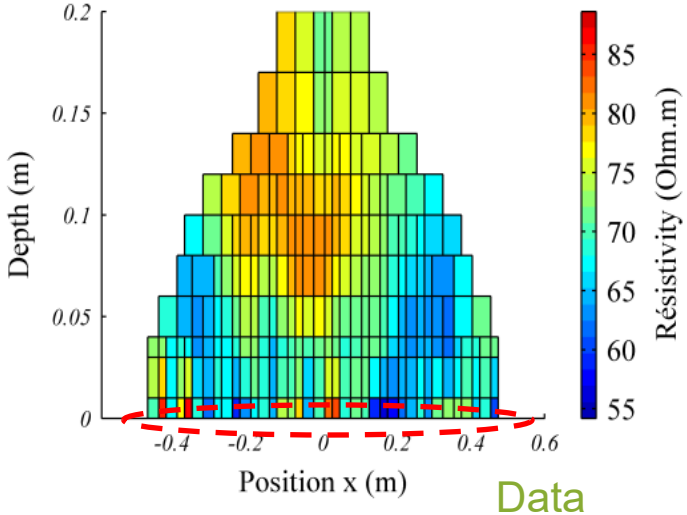
Figure 5.2 — Les trois étapes de la fabrication du capteur.



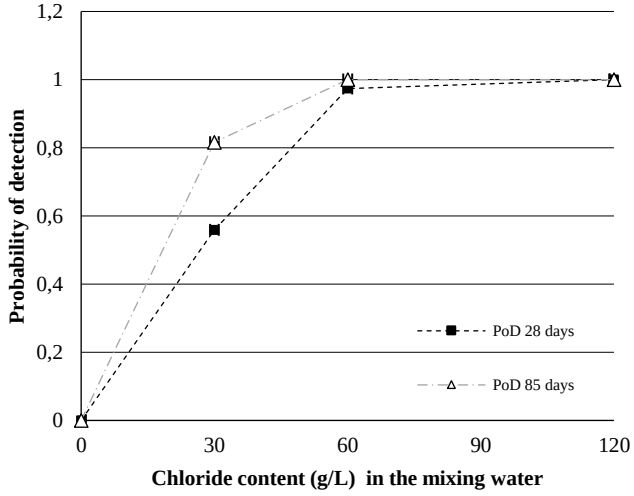
a) Experimental and fitted distributions of resistivity at 28 days



b) ROC curves for the detection of 30g/l of NaCl at 28 days.



Data

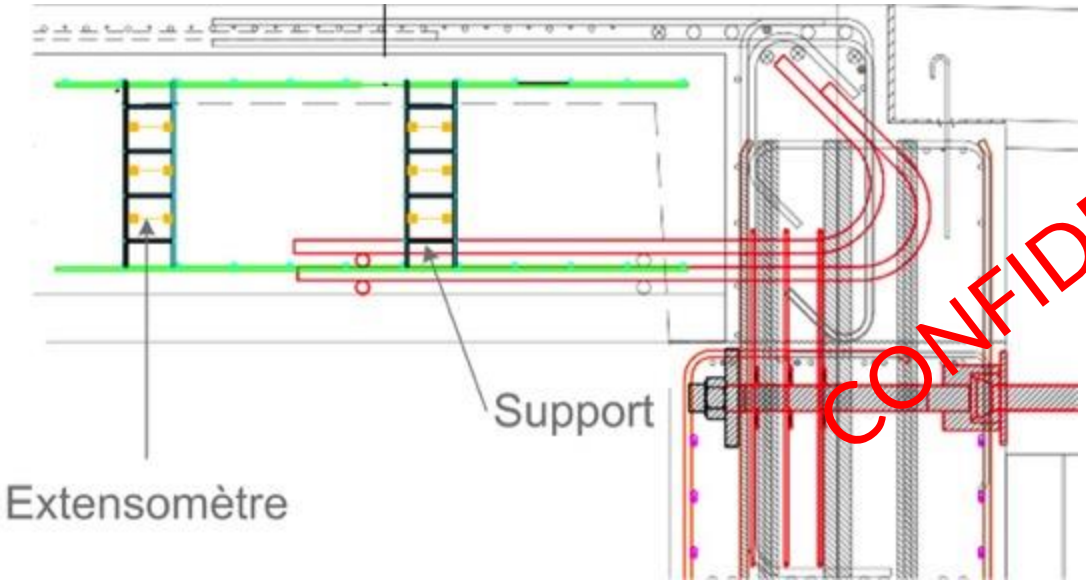


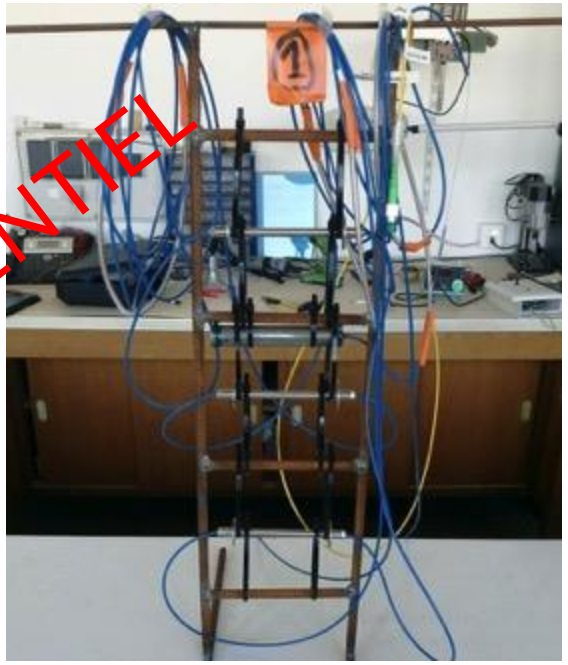
Chloride threshold detection

Part 3 – technologies and the needs

Damage and Chloride Ingress

Reduce time of onshore and maritime opérations (prefabrication of systems)





Part 3 – technologies and the needs

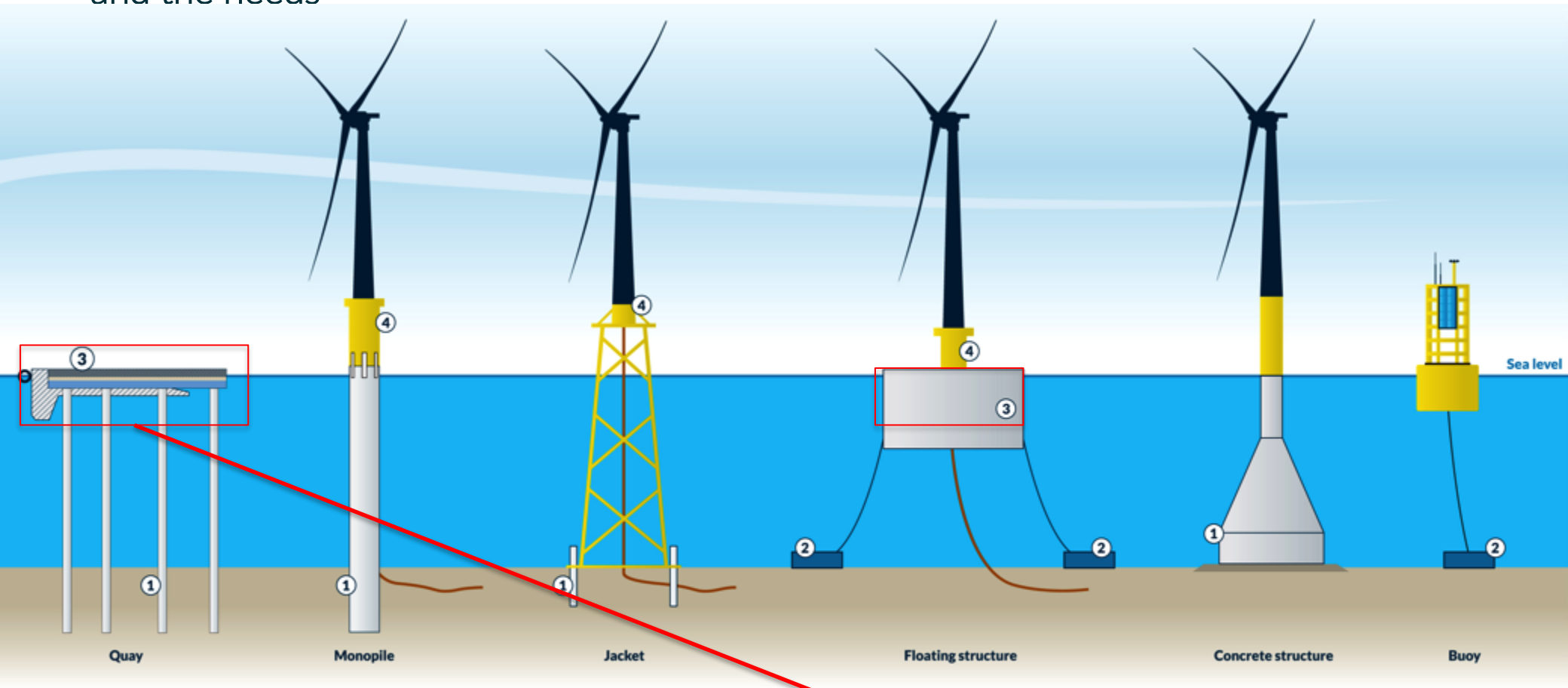
Damage and Chloride Ingress

3D monitoring of stresses (patent Sentilel)


Patent Sentinel
Université de Nantes

- Part 3 – technologies and the needs

Concrete slabs / Harbours

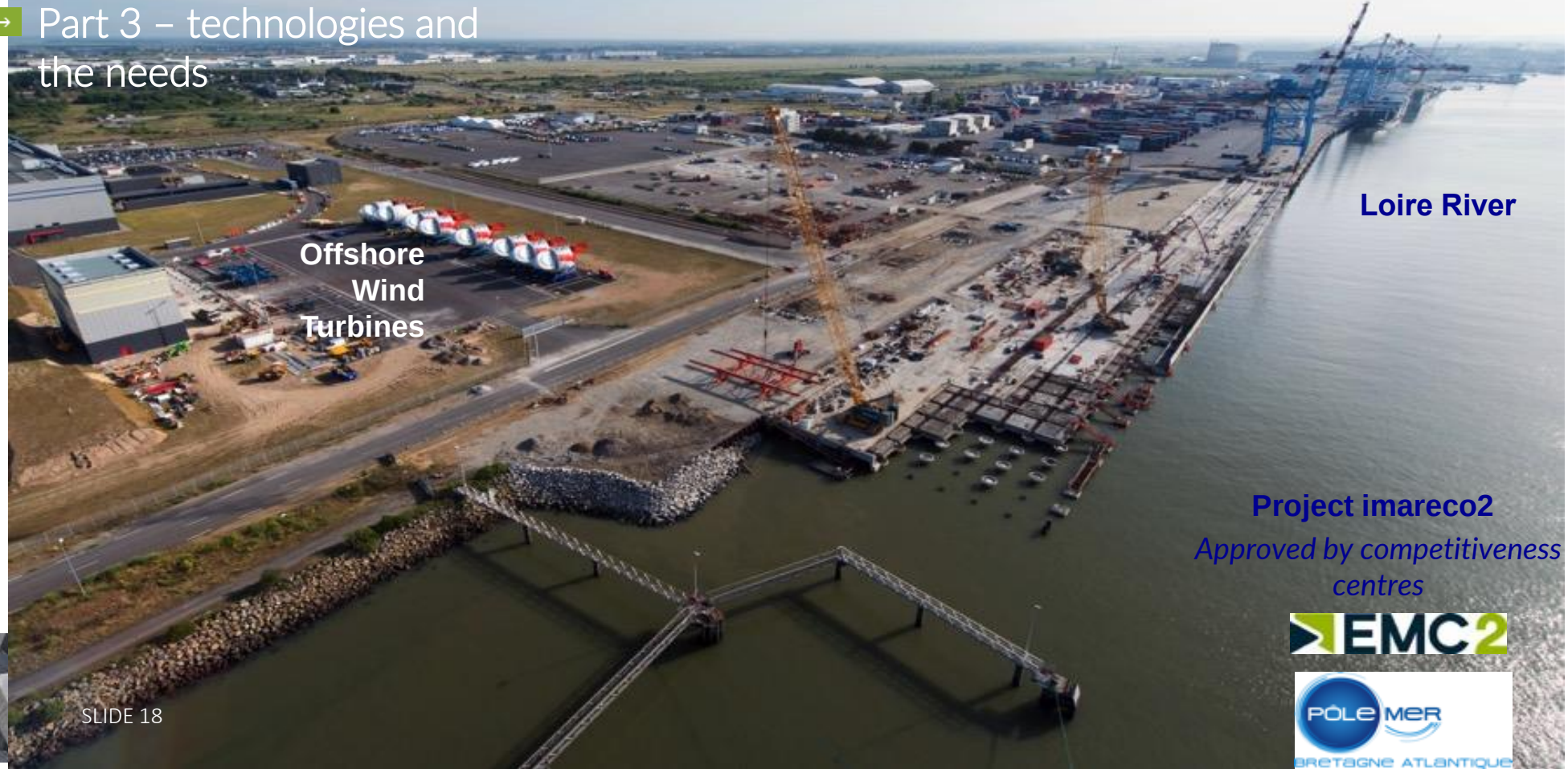


Source Neopolia

COST Action TU1402 – Quantifying the Value of Structural Health Monitoring

Existing video on youtube:
https://www.youtube.com/watch?v=h9u6l0aT9Ys
220 views (6 months)

Part 3 – technologies and the needs



Project imareco2

Approved by competitiveness centres

EMC2

PÔLE MER BRETAGNE ATLANTIQUE

Part 3 – technologies and the needs

Stresses

3D monitoring of stresses

Part 4 – Models and Methods

State of the Art

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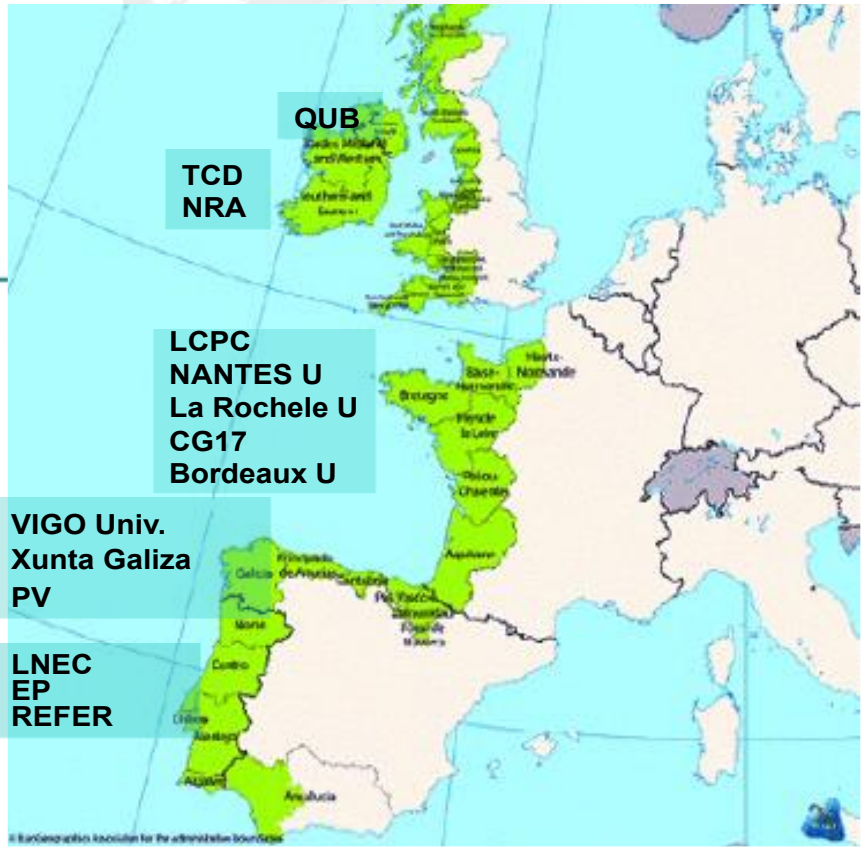
duratiNet

Durable Transport Infrastructures in the Atlantic Area Network

European Union
European Regional Development Fund

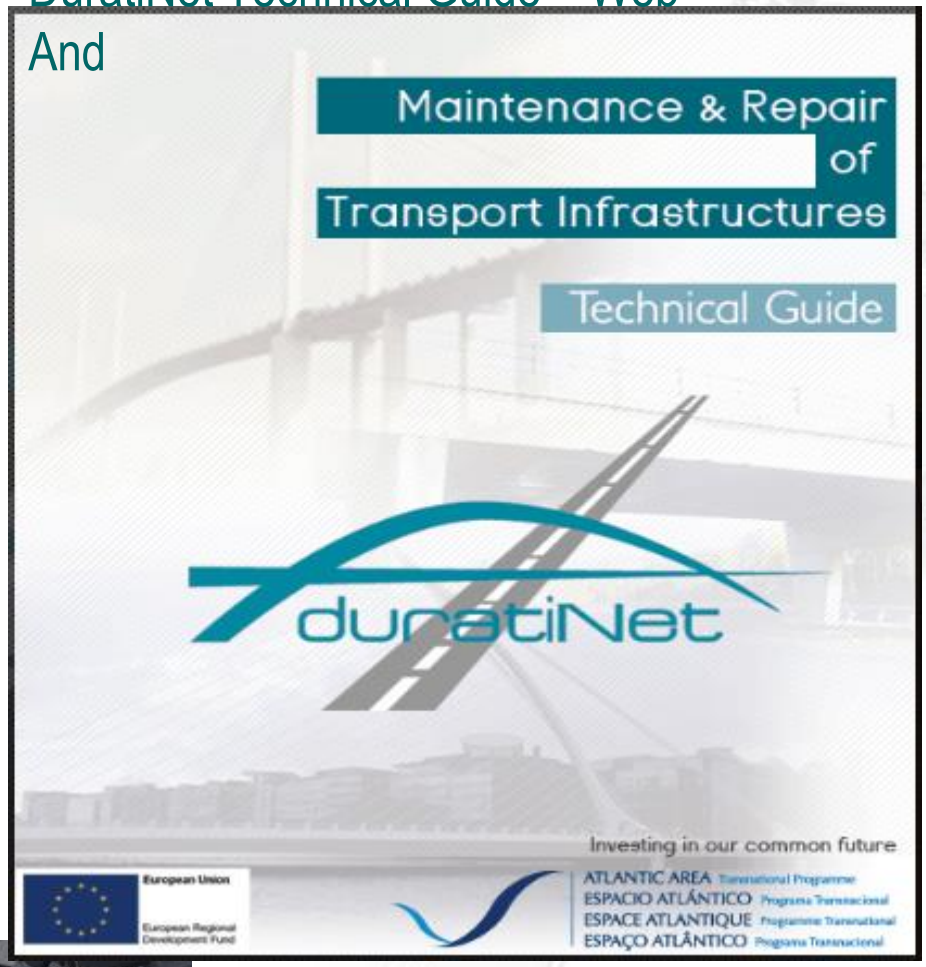
ATLANTIC AREA
Transnational Programme



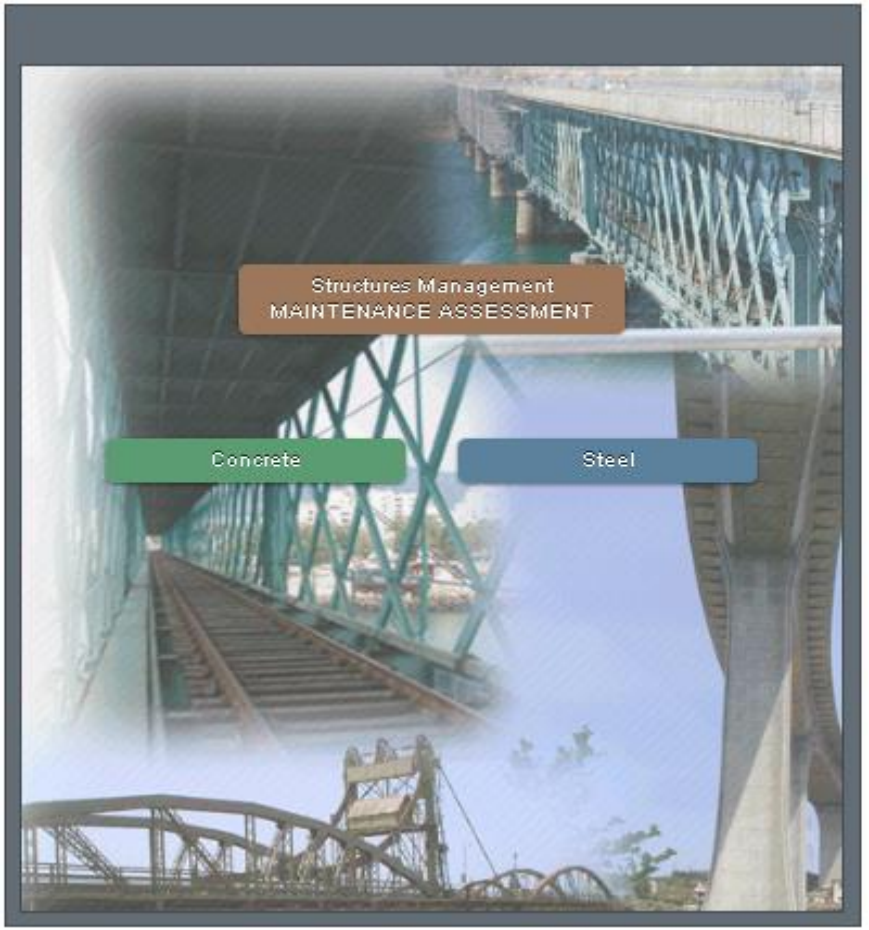
Part 4 – Models and Methods

DuratiNet Technical Guide – Web

And



State of the Art

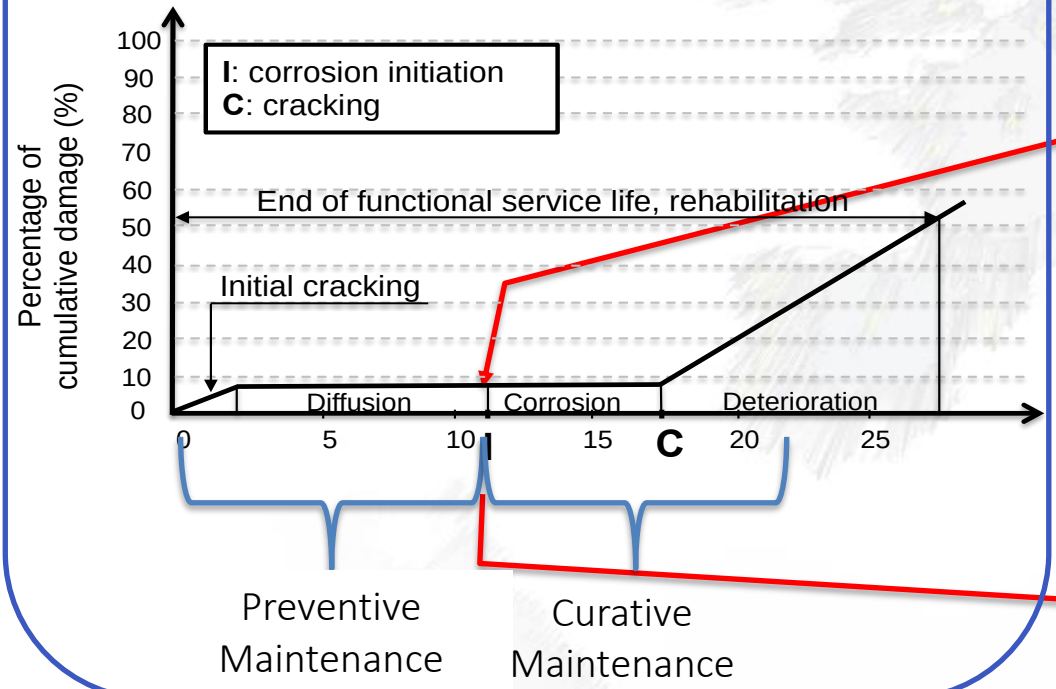


- Part 3 – technologies and the needs

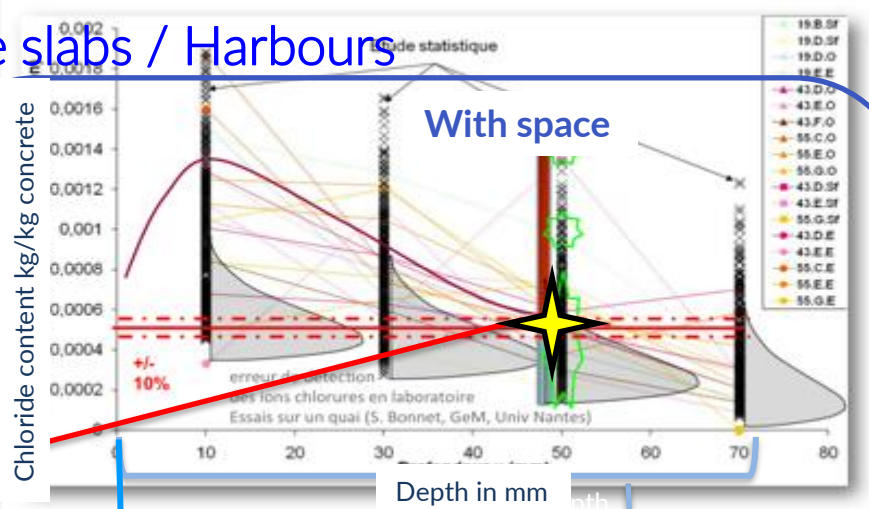
Concrete slabs / Harbours

Simulate the actions with their uncertainties
Focussing at this place (rebars)

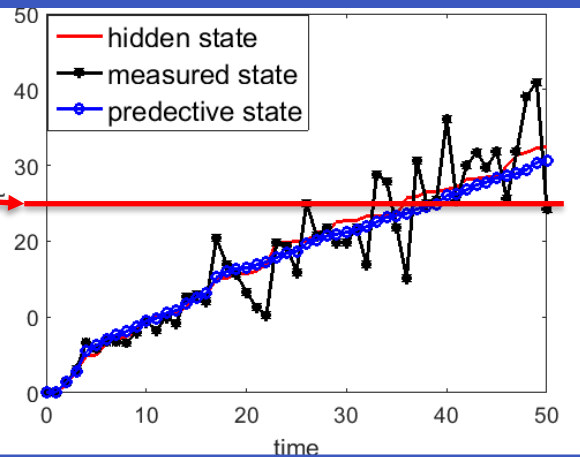
With time



With space



Simulate stochastic ingress of chlorides

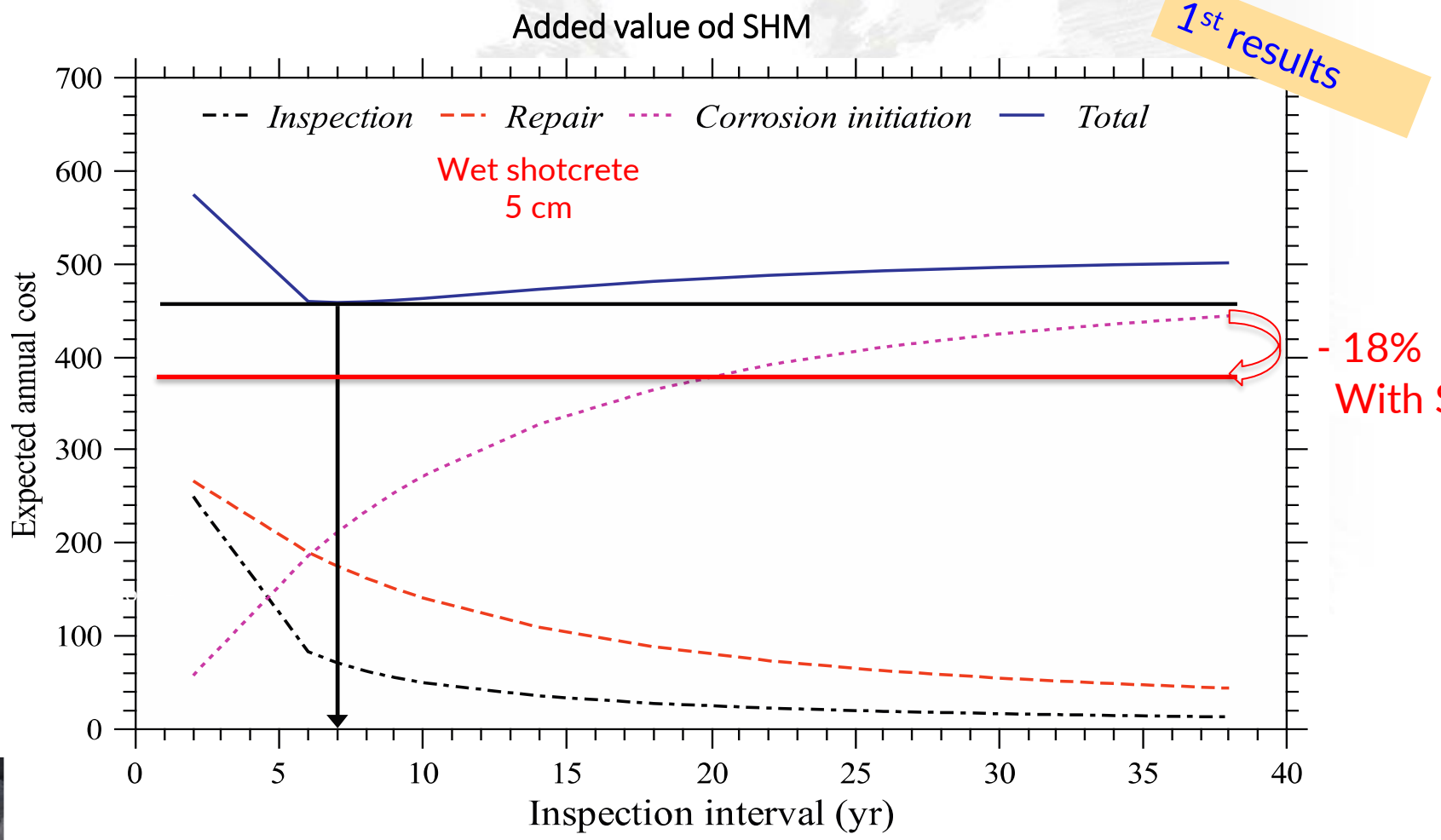


Monitoring reduces the uncertainties

- Part 3 – technologies and the needs

Concrete slabs / Harbours

1st results



- 18%
With SHM

Conclusion

A lot of progresses since the early 90's:
- Understanding of physical and mechanisms
- Stochastic modelling of chloride ingress
- Monitoring

Resilient challenges
- Fatigue
- Redundant monitoring for chloride ingress + corrosion threshold> SmartCore and Regional Project in Nantes
- Spatial variability (PhD defense in january 2021)
- Biofouling of concrete (reef effect)
- Effect of climate change (https://www.researchgate.net/project/Climate-change-effects-and-adaptation-of-civil-infrastructure-and-buildings)

More information

- https://www.researchgate.net/project/DURATINET
- https://www.researchgate.net/project/Universite-de-Nantes-in-EC-COST-Action-TU1402-Quantifying-Value-of-SHM
- https://www.researchgate.net/project/Structural-Health-Monitoring-of-Coastal-and-Offshore-Structures
- https://www.researchgate.net/project/Probabilistic-modeling-of-degradation-processes
- https://www.researchgate.net/project/Behavior-inspection-monitoring-and-maintenance-of-structures-special-focus-on-structures-in-marine-environment