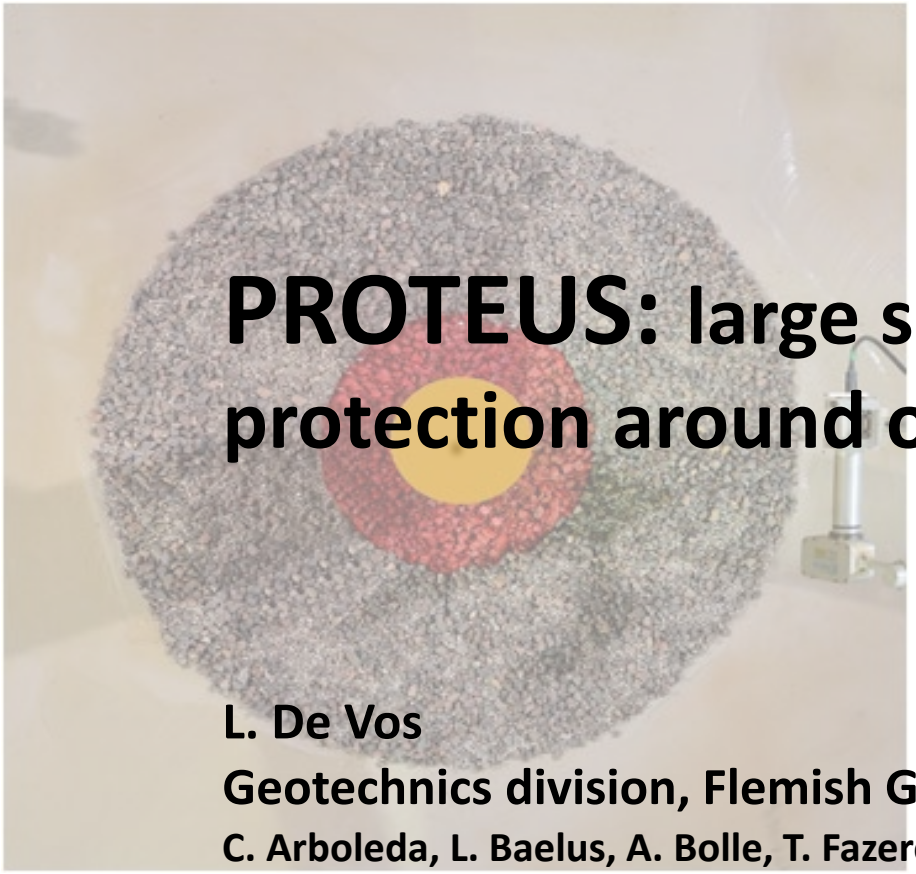
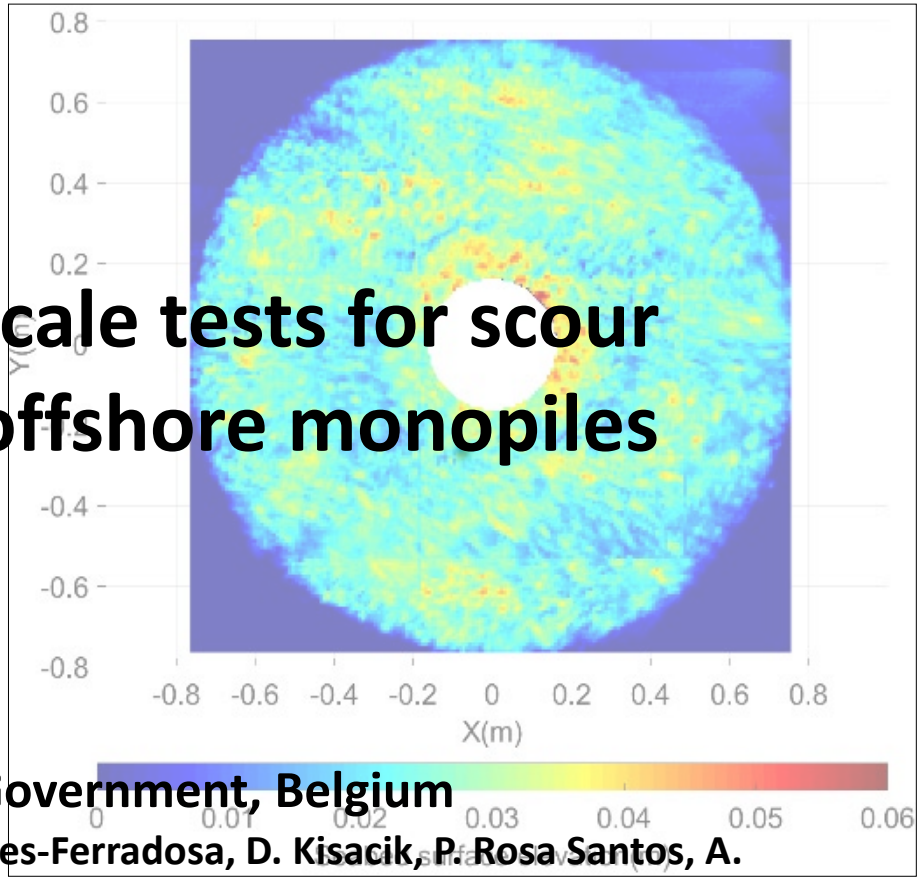


PROTEUS: large scale tests for scour protection around offshore monopiles



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Geotechnics division, Flemish Government, Belgium

C. Arboleda, L. Baelus, A. Bolle, T. Fazeres-Ferradosa, D. Kisacik, P. Rosa Santos, A. Schendel, T. Schlurmann, V. Stratigaki, V. Szengel, F. Taveira Pinto, D. Todd, P. Troch, R. Villanueva, M. Welzel, R. Whitehouse, M. Wu

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PROTEUS: Protection of offshore wind turbine monopiles against scouring

Vlaanderen
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UNIVERSITY

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FEUP FACULDADE DE ENGENHARIA
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Working with water

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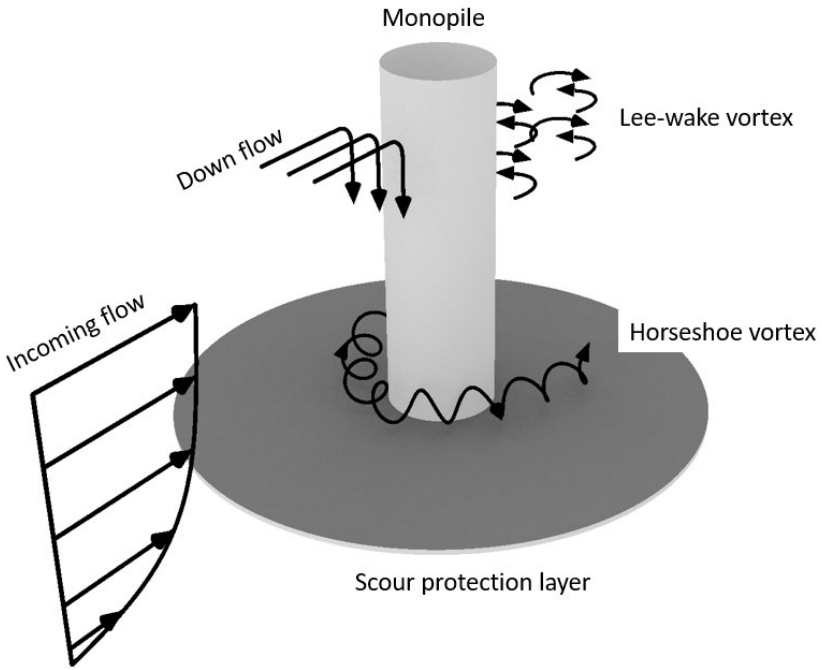
Flow around a monopile foundation

- **Presence of pile disturbs the flow:**
  - Local increase of bed shear stress leads to scour
  - Scour protection is often applied



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Static stability versus dynamic stability

- **Static stability: no movement of stones:**

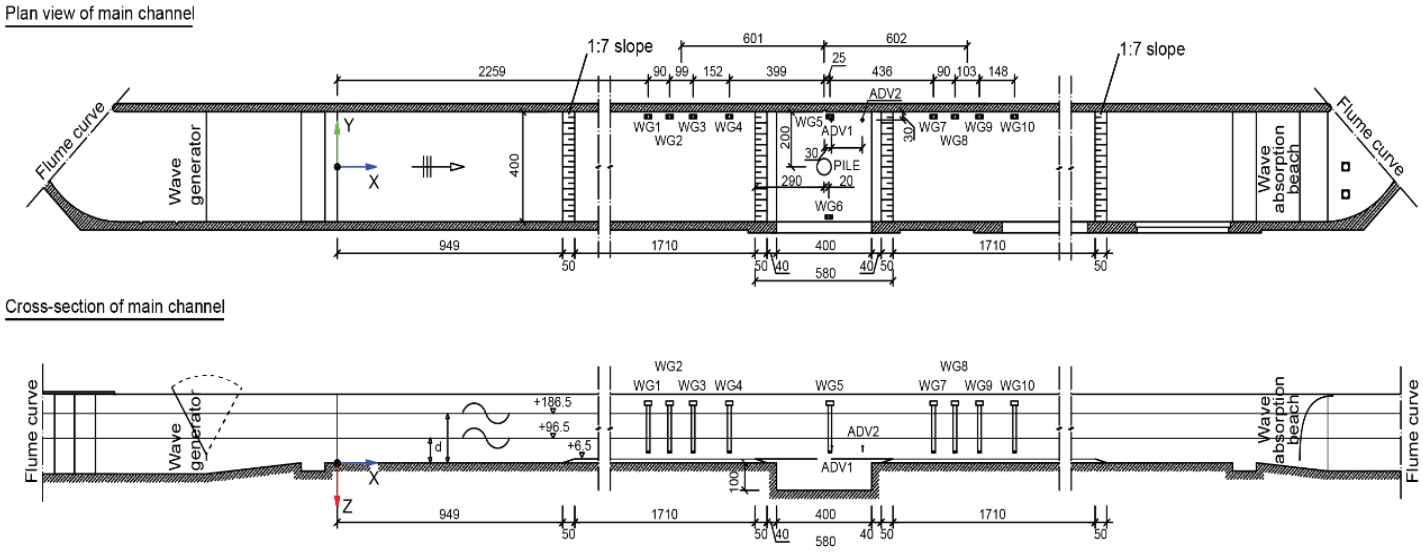
$$\tau_{cr,pred} = 1.659 + 3.569\tau_c + 0.765\tau_w$$

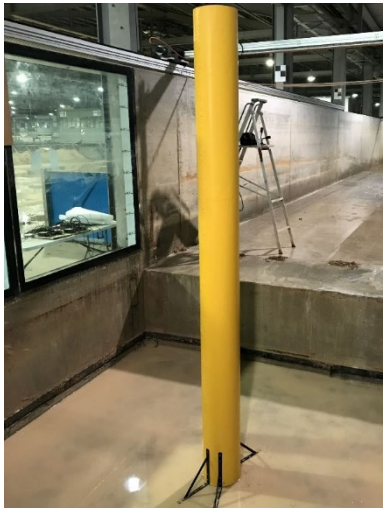
- **Dynamic stability: accepted movement of stones without failure:**

$$\frac{S_{3D}}{N^{b0}} = a_0 \frac{U_m^3 T_{m-1,0}^2}{\sqrt{gd}\,(s-1)^{3/2} D_{n50}^2} + a_1 \left(a_2 + a_3 \frac{\left(\frac{U_c}{w_s}\right)^2 (U_c + a_4 U_m)^2 \sqrt{d}}{g D_{n50}^{3/2}} \right)$$

- **Gaps:**
  - Scale effects
  - Influence of wave-current direction
  - Influence of large flow velocities
  - Use of wide graded (smaller) stones

HR Wallingford: test set-up in the Fast Flow Facility





- Main working channel size: 57m in length, 4m in width
- Secondary working channel: 50m in length, 2.6m in width
- Water depth: 0.8m to 2m
- Hinged flap type multi-element wavemakers with active wave absorption
- Reversible pumps which support current following waves and opposing waves
- 1m deep, 4m long and 4m wide sand pit.

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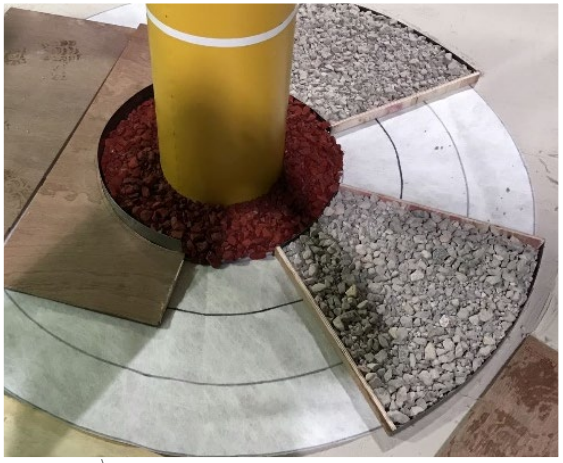
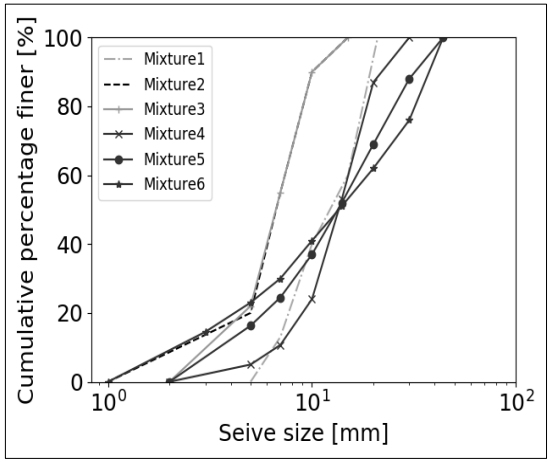
HR Wallingford: test set-up in the Fast Flow Facility

- **Main focus on:**
  - Scale effects: scale 1/8,33 and 1/16,67
  - Different gradings and application of wide graded (smaller) stones
- **Large scale offers challenges with regard to test set-up!**





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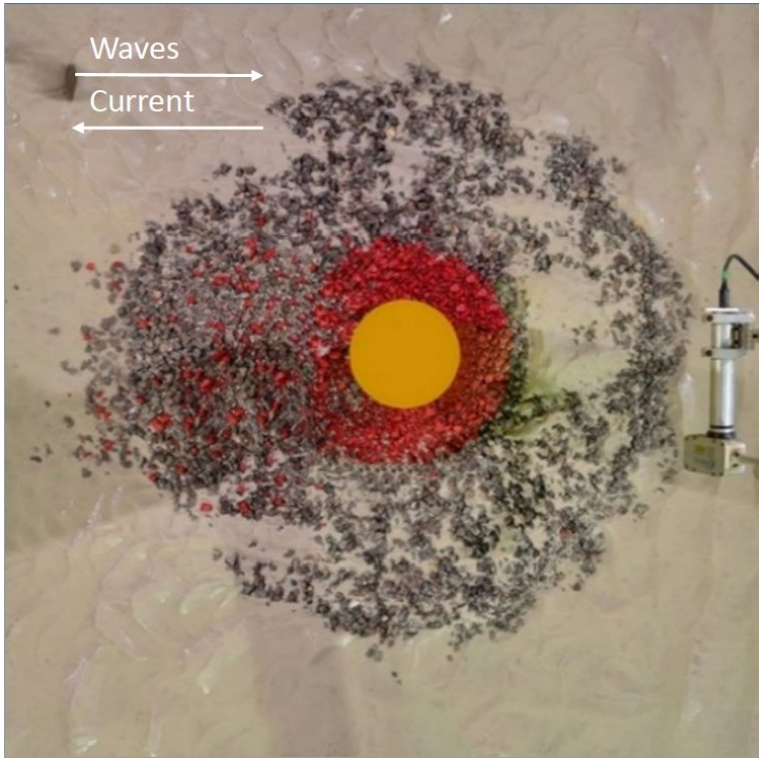
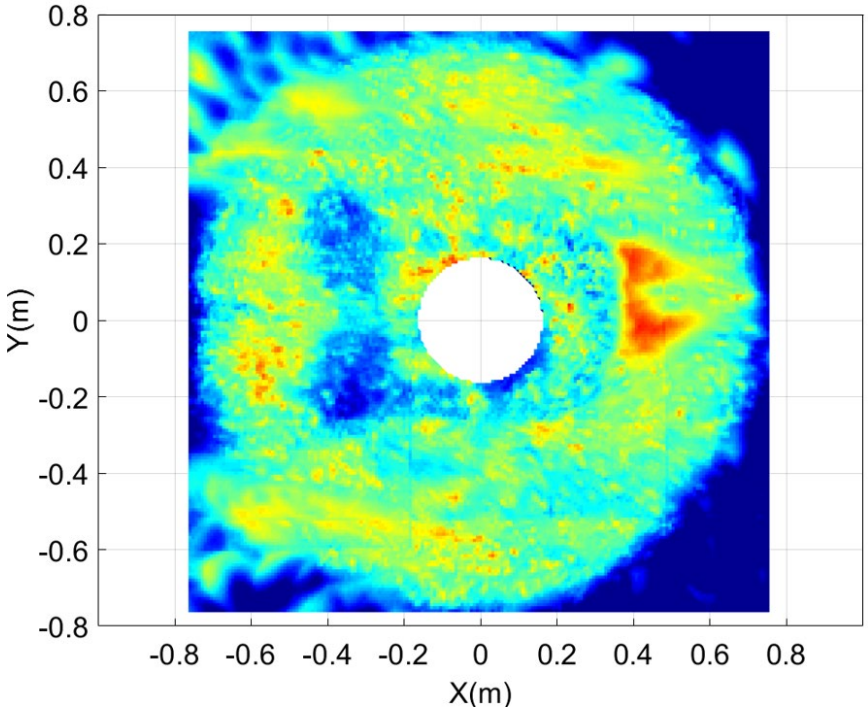
Some results

- **Reverse current also leads to largest damage in large scale tests**





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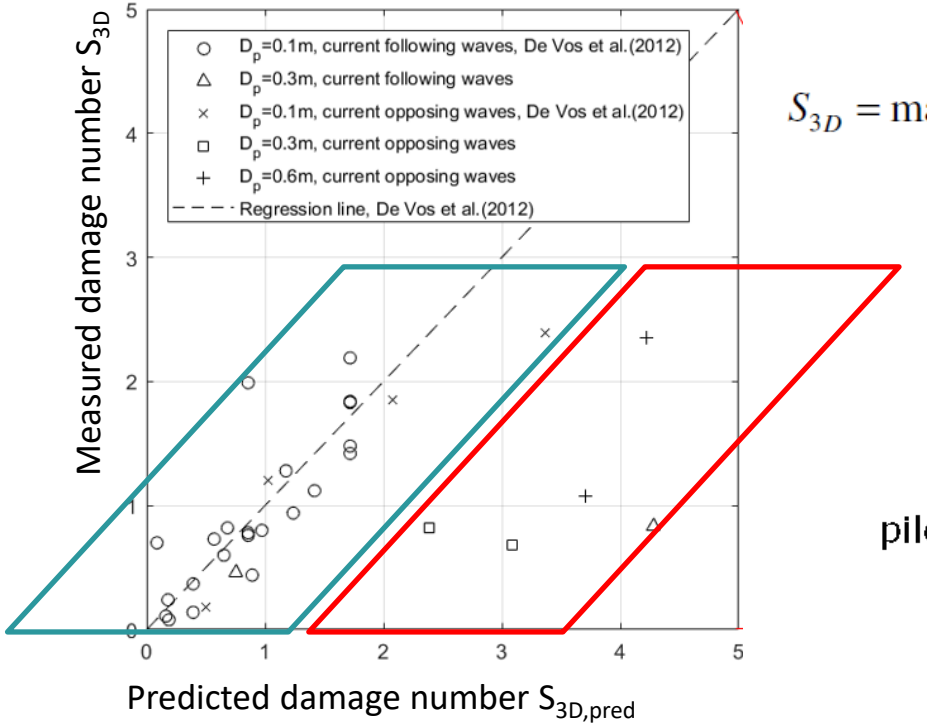
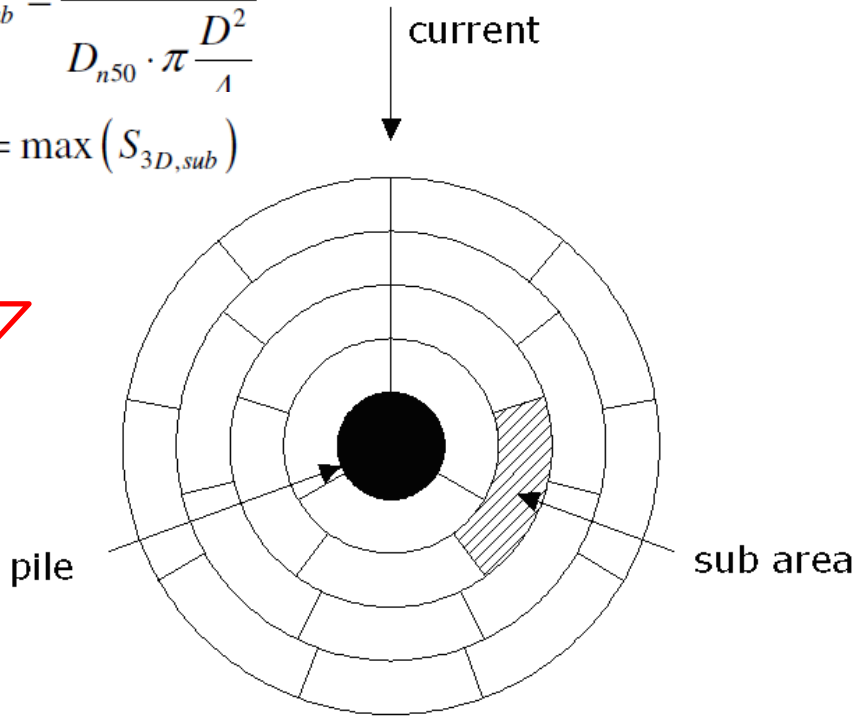
Some results

- **Clear (scale) effects: small scale tests appear to be on the conservative side**



$$S_{3D,sub} = \frac{V_e}{D_{n50} \cdot \pi \frac{D^2}{A}}$$

$$S_{3D} = \max\left(S_{3D,sub}\right)$$



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Near future

- **Papers are in preparation**
- **Extra set of small scale tests to reproduce the Proteus experiments**
- **Numerical modelling in combination with experimental tests can lead to optimal understanding of physics, leading to an optimal design!**