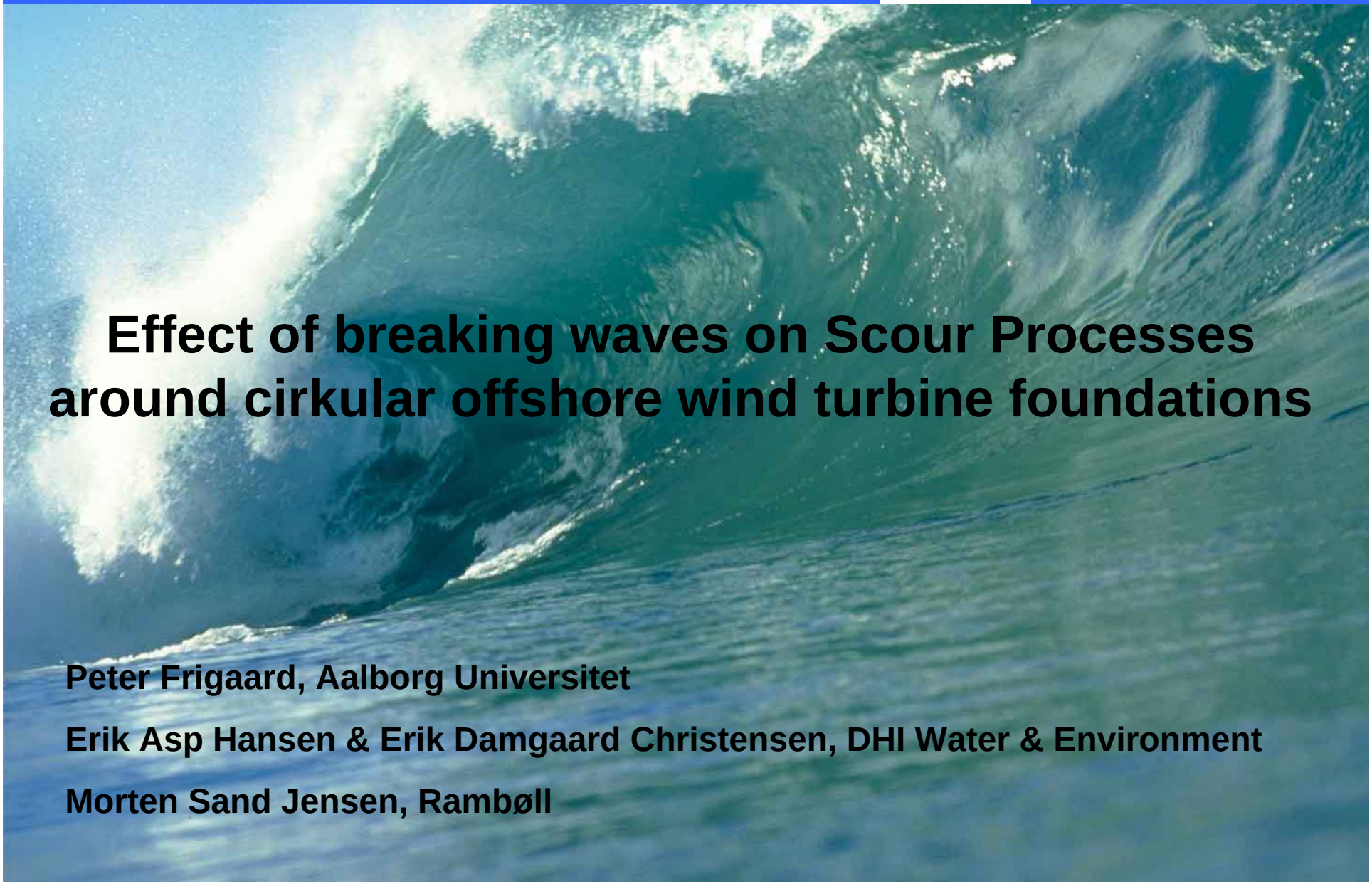
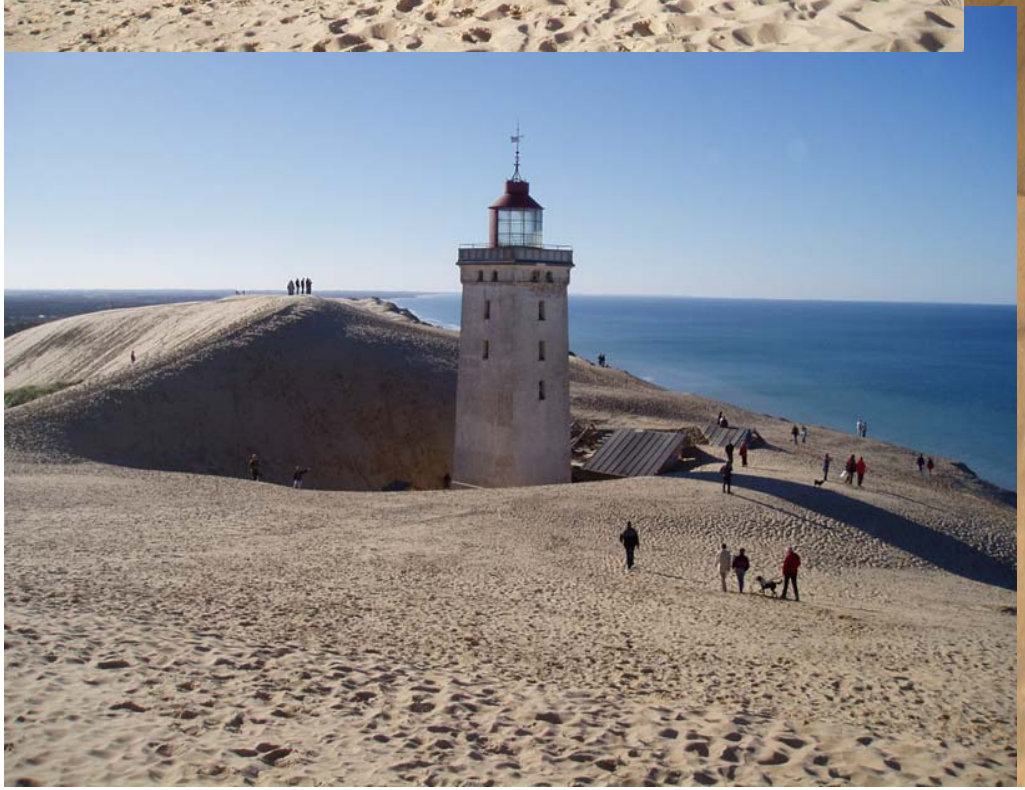


Effect of breaking waves on Scour Processes around cirkular offshore wind turbine foundations

Peter Frigaard, Aalborg Universitet

Erik Asp Hansen & Erik Damgaard Christensen, DHI Water & Environment

Morten Sand Jensen, Rambøll



- Scour (and scour protection) are major issues to consider when constructing offshore wind farms
- No scour protection means that a scour hole will develop
- The engineer can either include the scour in his design, or he can place a scour protection on the seabed

For many years, engineers designing bridges have been used to taking into account scour around structures exposed to steady currents. The fully developed scour depth in a uniform current is 1 to 1.5 times the pile diameter, resulting in a typical maximun scour depth in the range of 5-8 meter for a typical pile

Wave scour has only recieved little attention. Almost no attention on scour from breaking waves.

Outline of my presentation

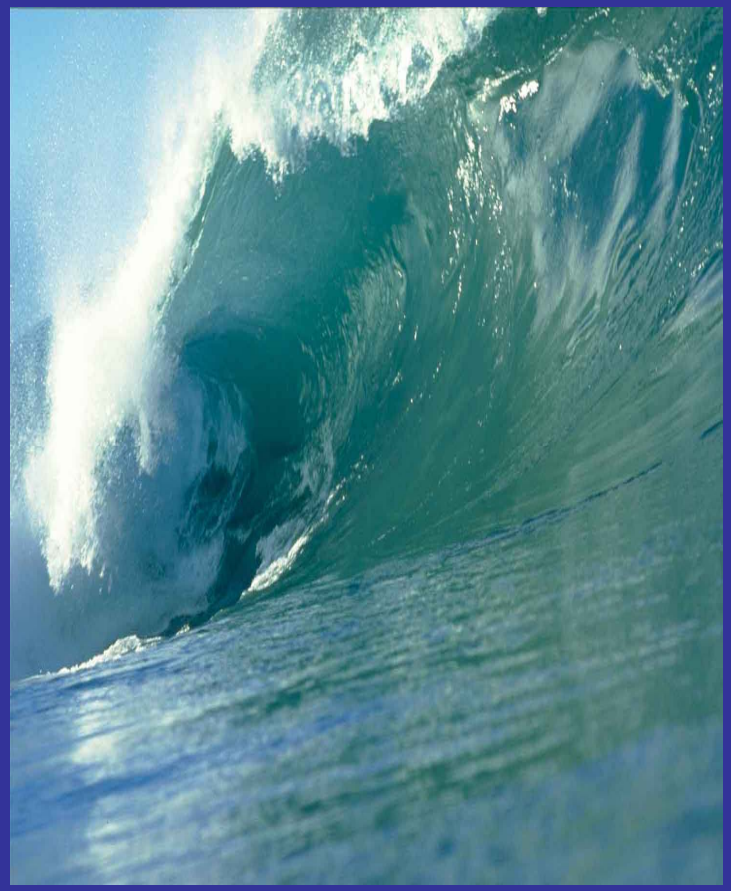
- Kill the myth that breaking waves will generate more scour than non-breaking waves do

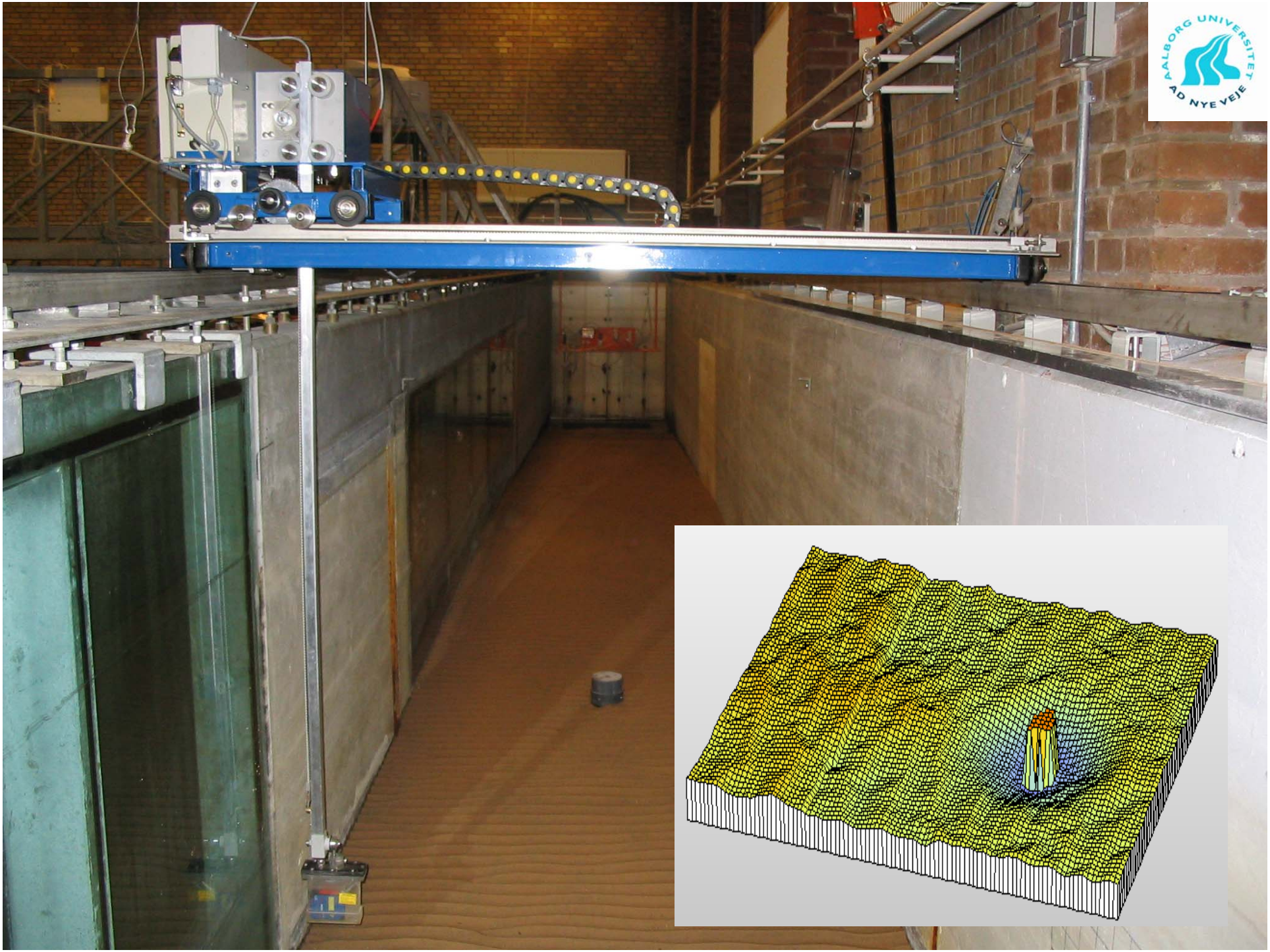
  -- Show scour tests from laboratory

  -- Show PIV measurements of flow field

- Demonstrate that a VOF model can calculate the flow field around a pile correct.

  -- Compare PIV measurements with results from VOF model




AALBORG UNIVERSITET
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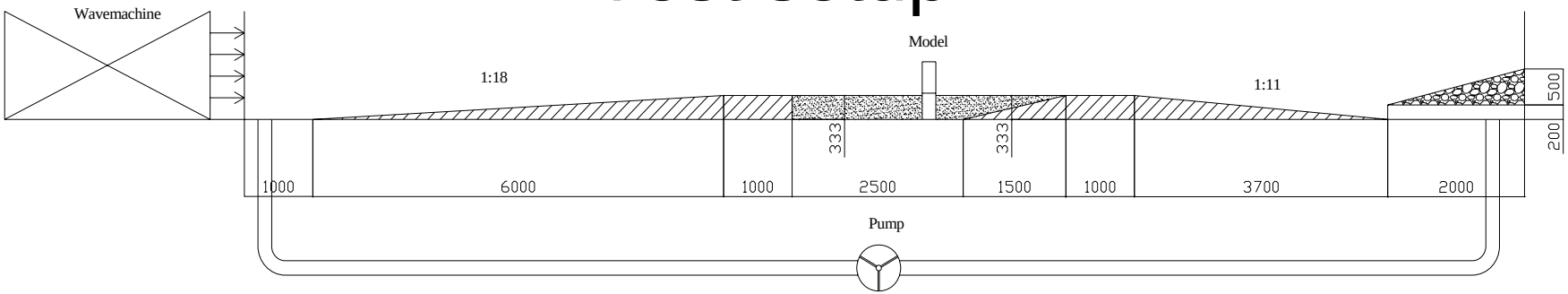
Test setup

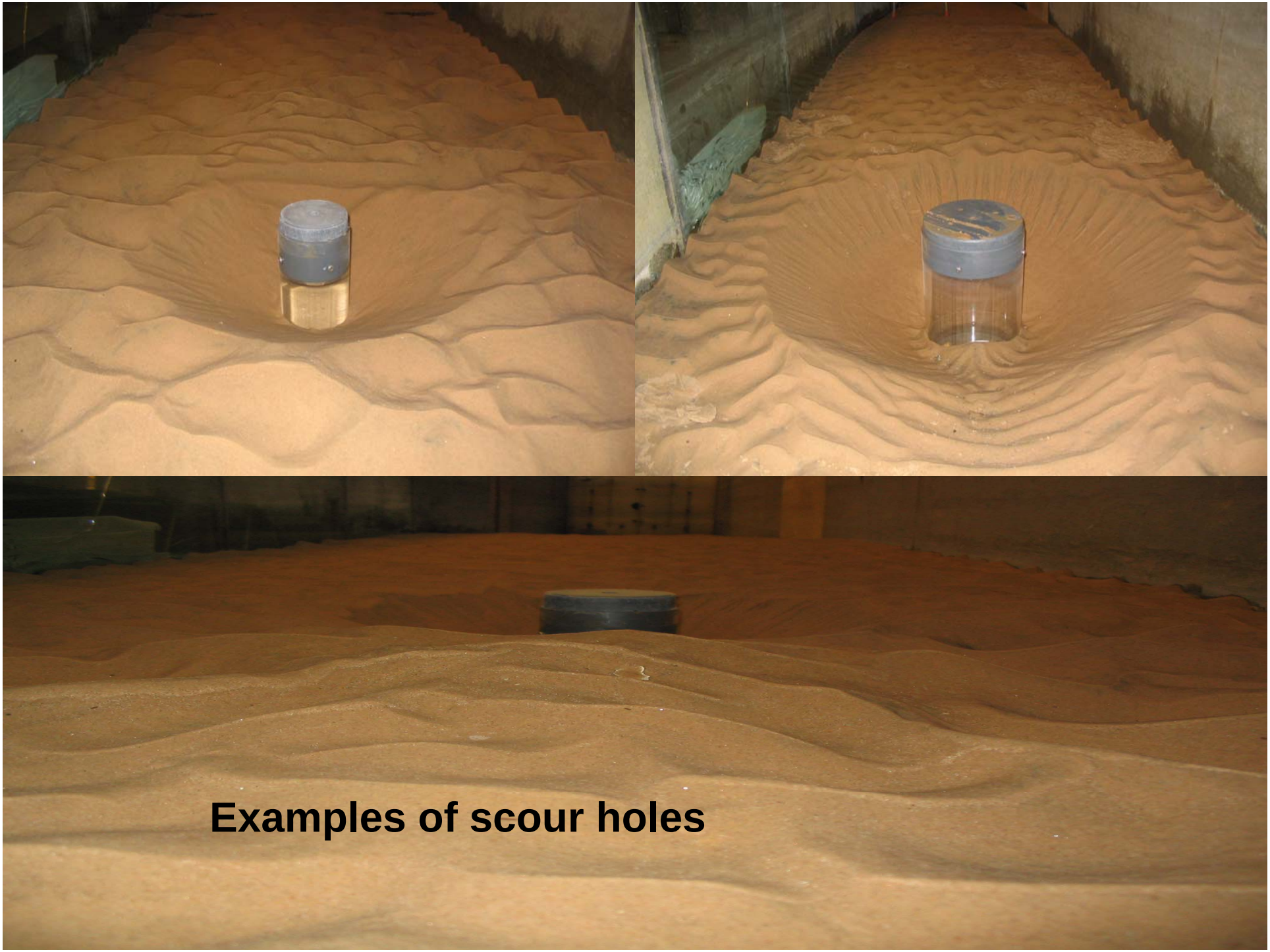


- Possible to make strong tidal currents
- Slope 1:18 -> breaking waves
- Tests performed as part of Offshore Center Denmark project: Offshore wind turbines situated in strong sea currents. 9/2-2006 seminar in Esbjerg, Denmark
- Today: The tests with breaking waves.

Development of scour hole

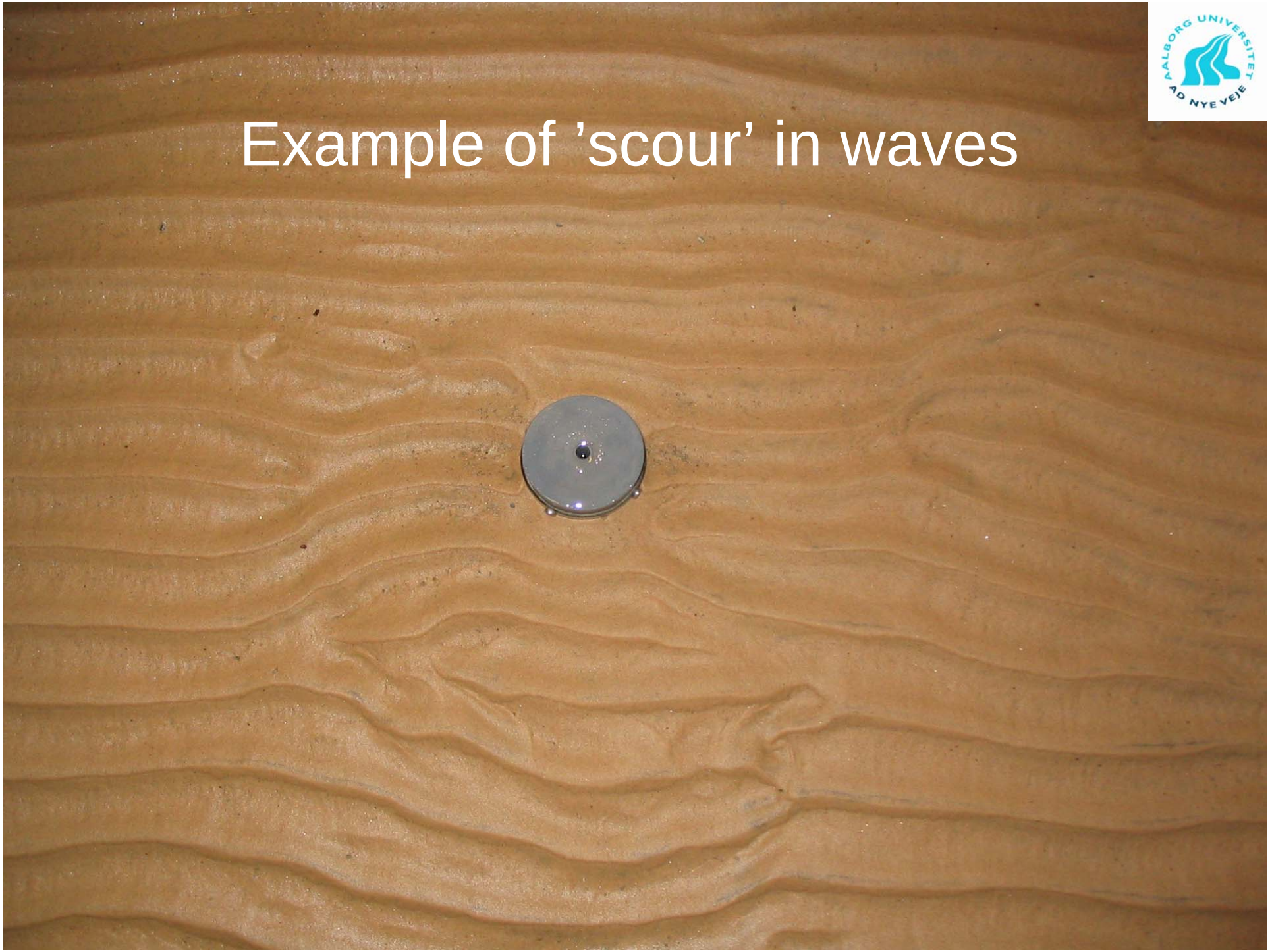
a) Current. U=0.3 m/sec
b) Current and waves. U=0.3 m/sec, Hs=0.12 m, Tp=1.97 sec.

water depth=0.29 m, pile diameter=0.10 m.



Examples of scour holes

Example of ’scour’ in waves

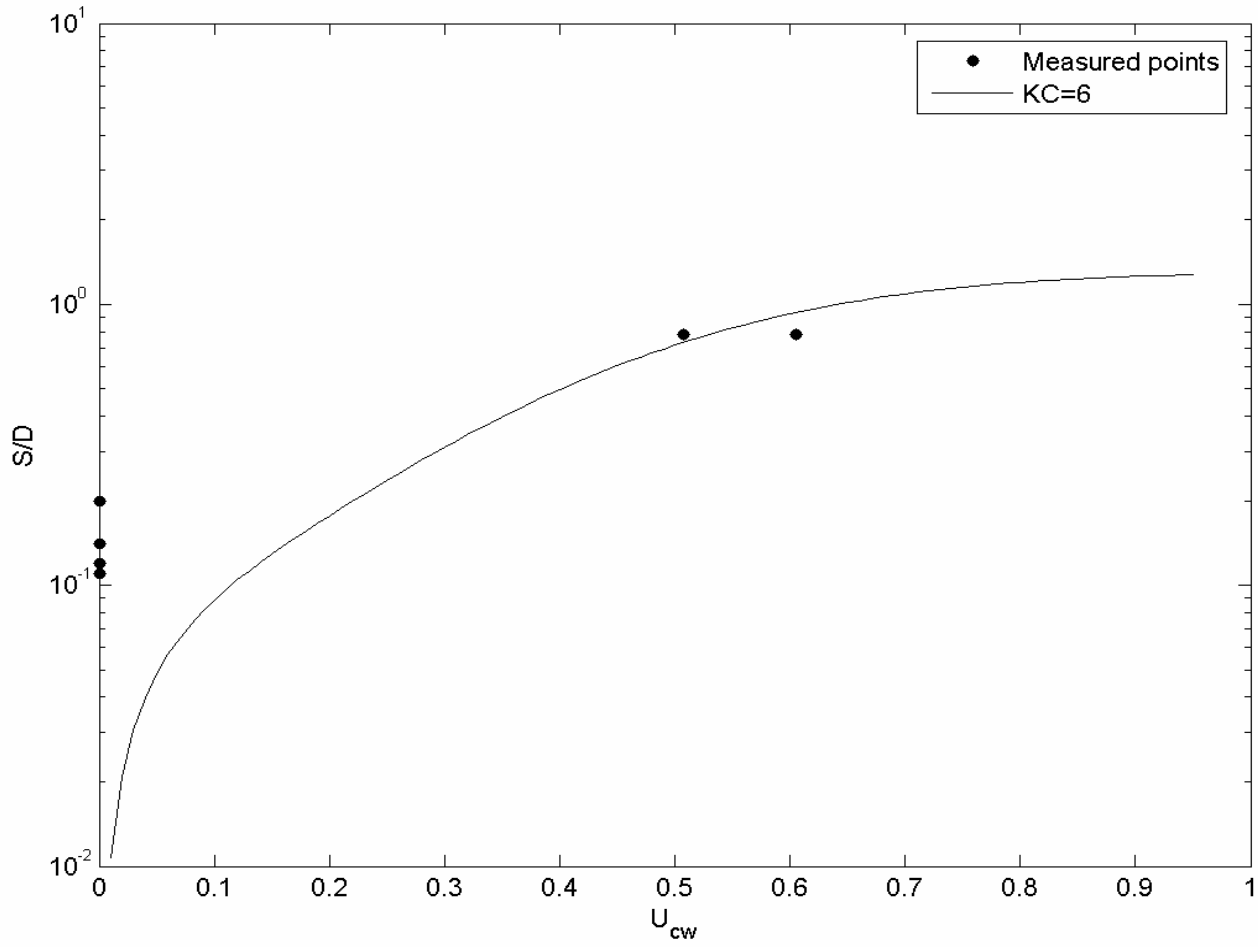


Design considerations

- In a combination of waves and currents, the scour hole becomes less than in currents alone
- In pure waves, the scour depth increases with the KC number
- Only current: S/D=1.3 (somethimes +0.6)
- Combination of current and non-breaking waves

  Ucw=Uc/(Uc+Um). S/D=F(Ucw) [0 to 1.3].
- Breaking waves S/D=2.5

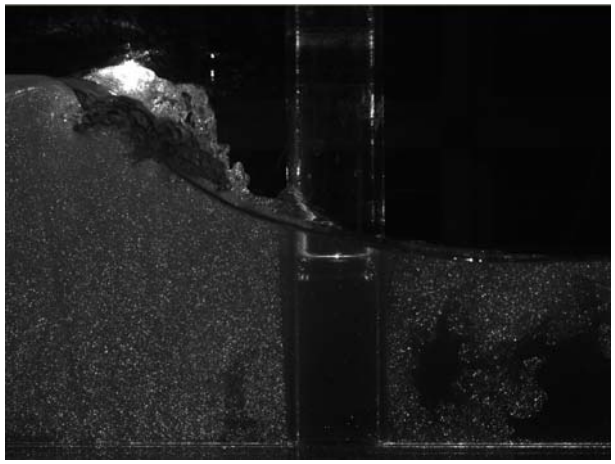
  (Based on work of a Dutch student doing tests on a unstable beach. Measured scour was scour + global erosion).


Measured points
KC=6
S/D
10^{1}
10^{0}
10^{-1}
10^{-2}
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
U_{cw}

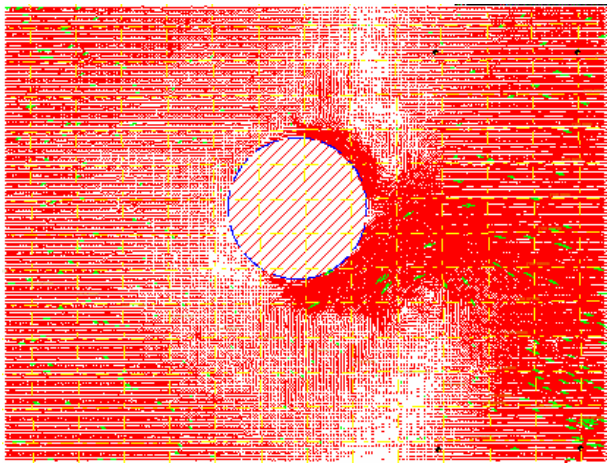
Why do we not get more scour in breaking waves than in non-breaking waves?

PIV measurements: breaking waves (regular waves)

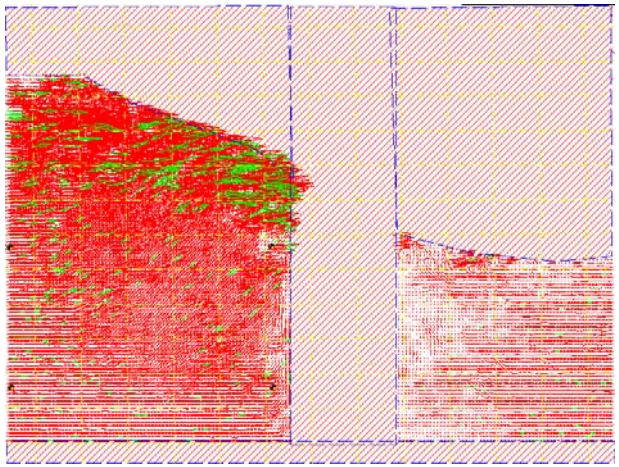
Breaking waves



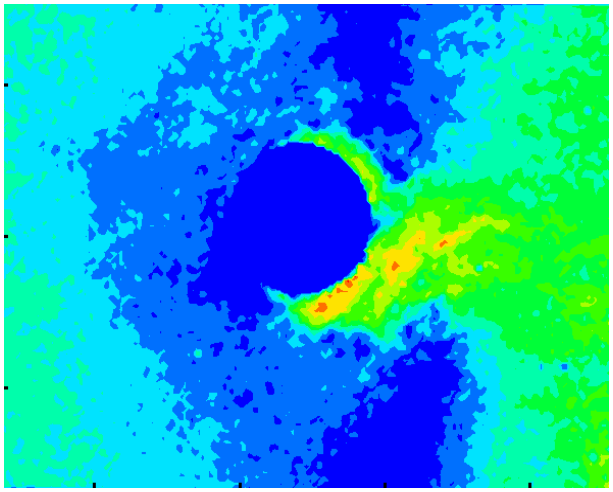
Pile diameter: 0.05m
Water depth at pile: 0.12m
Wave height: 0.10m
Wave period: 1.48s
KC: 12.4



The wave is just about to break in front of the pile.
Large vortices shed from the pile.

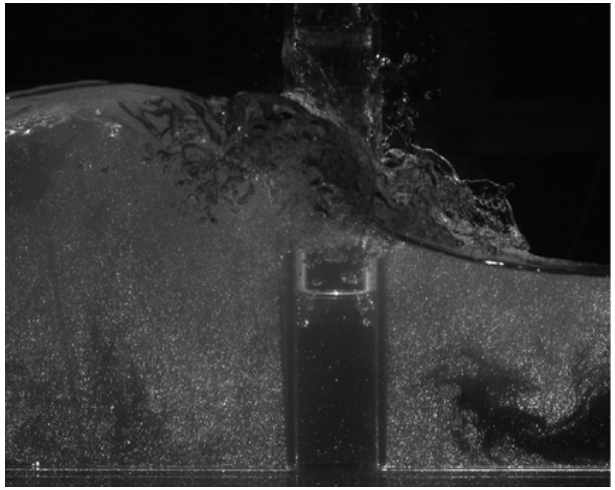


Velocities are very high in the upper part of the water depth, but remain limited at the bottom



PIV measurements: breaking waves (regular waves)

Breaking waves



Pile diameter: 0.05m
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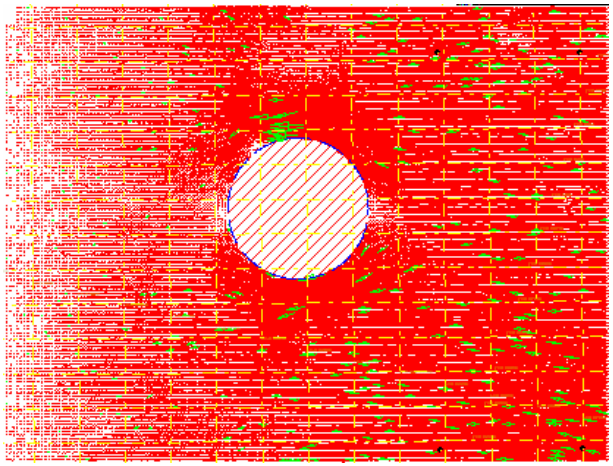
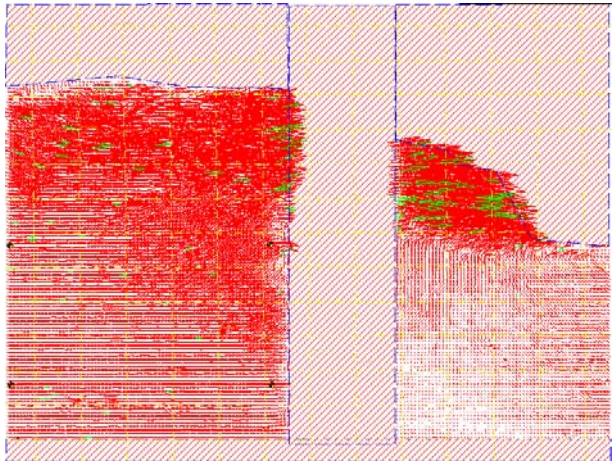
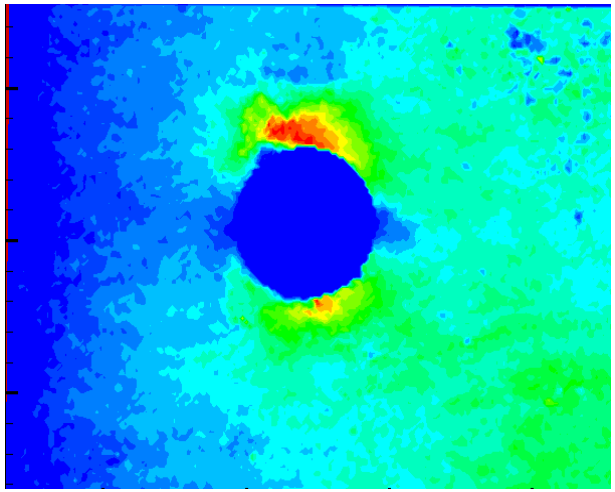


The wave has broken. Velocities are maximal. The maximum friction velocity near the pile is 4 times the maximum friction velocity in the undisturbed zone (both location, extension and value are comparable to results with non-breaking waves.



Velocities are very high in the upper part (2/3) of the water depth (much higher than for non-breaking waves), but remain limited (comparable to non-breaking waves) at the bottom



Why do we not get more scour in breaking waves than in non-breaking waves?

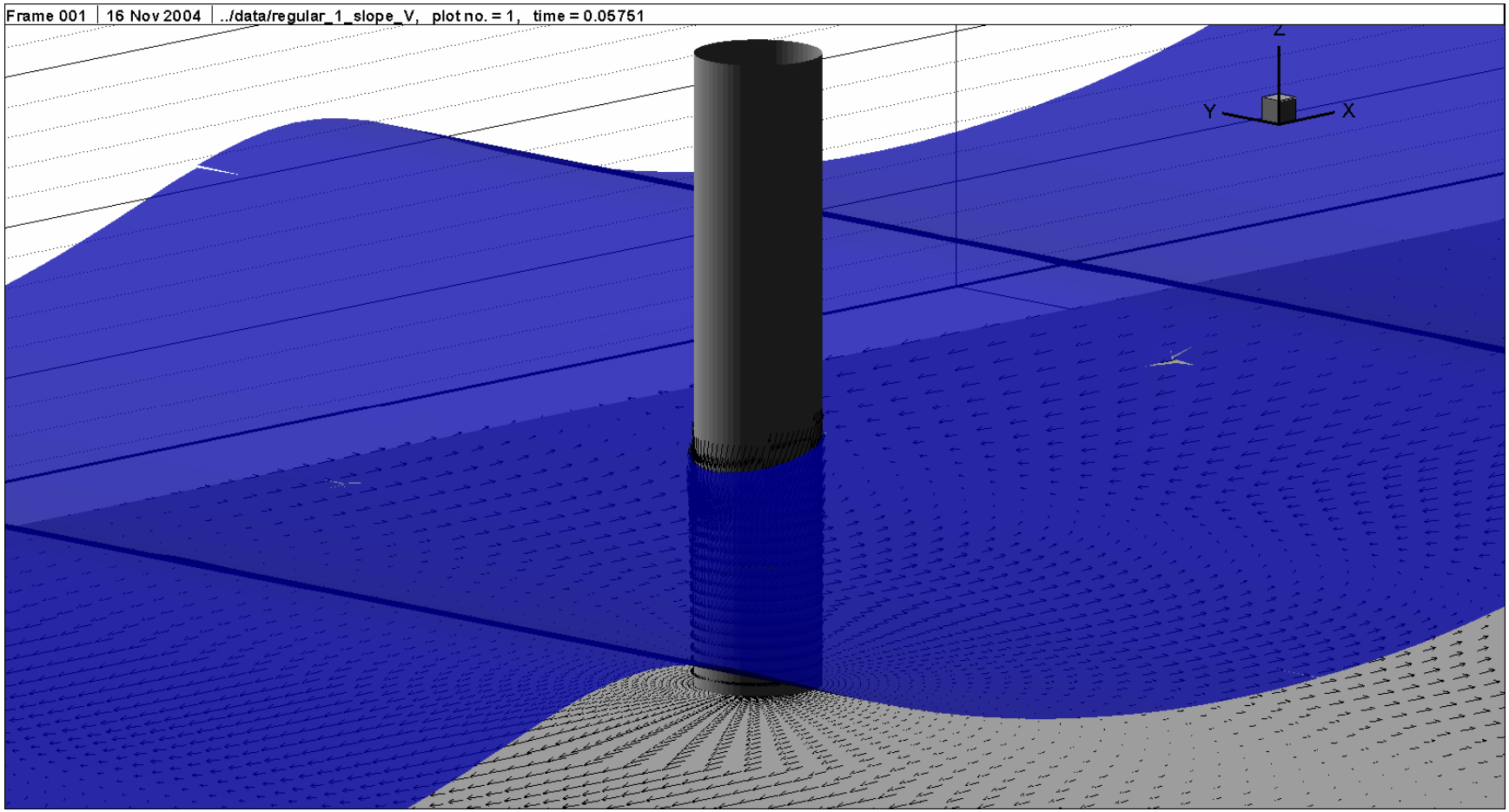
Velocities are very high in the upper part (2/3) of the water depth (much higher than for non-breaking waves), but remain limited (comparable to non-breaking waves) at the bottom.

Part 2: Numerical Investigations

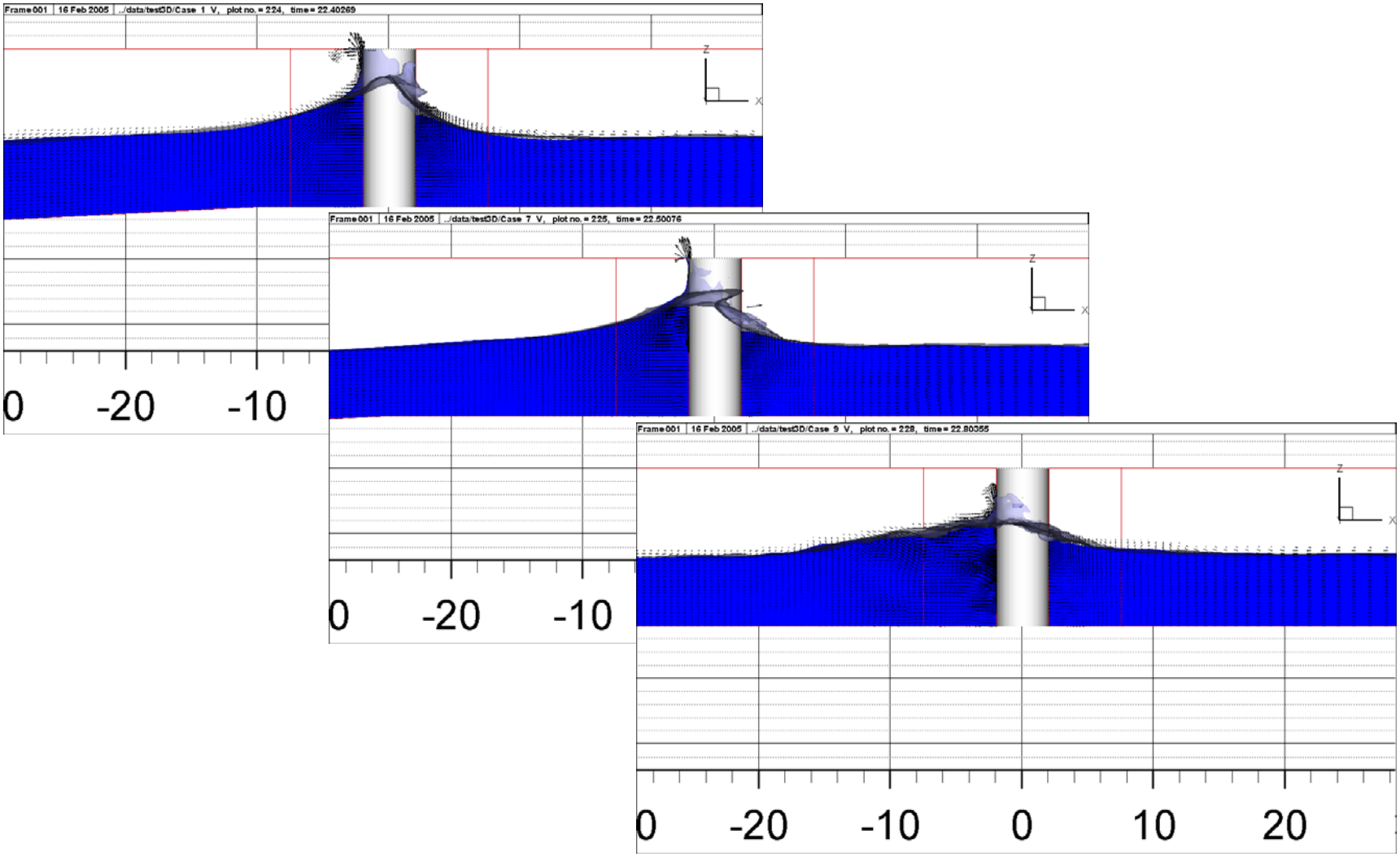
- Model: DHI’s NS3 model
- Three-dimensional Navier-Stokes solver
- Volume-of-fluid (VOF) description

- I will show a few examples demonstrating that such models are very powerfull tools to describe the flow field.

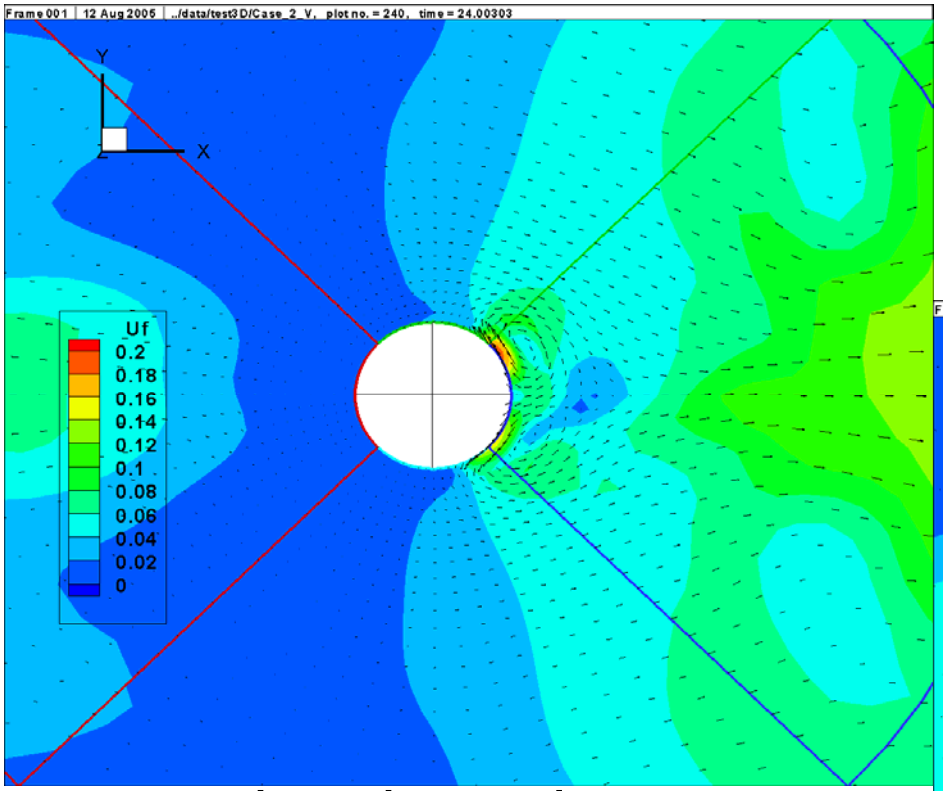
Example of flow field around a pile in breaking waves



Influence of distance on the breaking wave

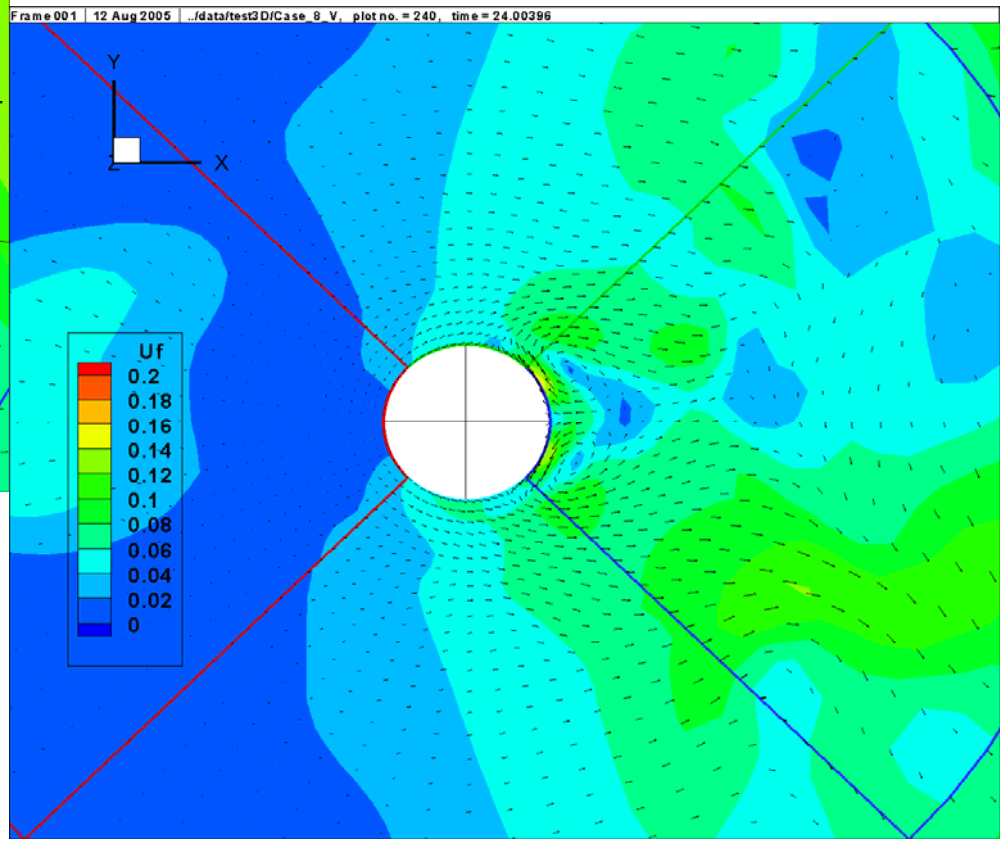


Friction velocity at the bed



Wave breaks at the center-line

Wave breaks before center-line



Conclusions

- Breaking waves do NOT increase scour
- VOF models can be used to calculate flowfield around foundations