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Case Study

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CASE STUDY: IMPLEMENTATION OF THE BUCKET FOUNDATION CONCEPT

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The Project

Cost reduction has been the driving force in development of a prototype foundation of a novel principle, the bucket foundation. The R&D-project includes an analytical model and 2/3-D FEM-models that can be regarded as universal model concerning the aspect of soil/structure interaction obtaining loads from an offshore wind turbine. The principle is used for a Vestas V90-3.0 MW turbine as a prototype in the test field for offshore wind turbine research, which has been built in connection with a joint R&D-program between Aalborg University and MBD Offshore Power. This test field is today part of the NearshoreLAB complex.

The stability of the foundation is ensured by a combination of earth pressures on the skirt and the vertical bearing capacity of the bucket.

Lowering the pressure in the cavity between the bucket and the soil surface insures the installation process. Model tests have been performed on buckets from 50 mm to 400 mm with skirt length varying from 0 to the same as the diameter of the bucket.

Further test regarding load, installation method, control of the inclination and control of the penetration rate are carried out in the test field in Frederikshavn with a 2-meter bucket and a 4-meter bucket.

The prototype is on-line monitored for dynamic response and analyses. In the laboratory, tests up to 500 mm buckets are carried out in a pressure tank with dynamic load to study the soil/structure interaction.

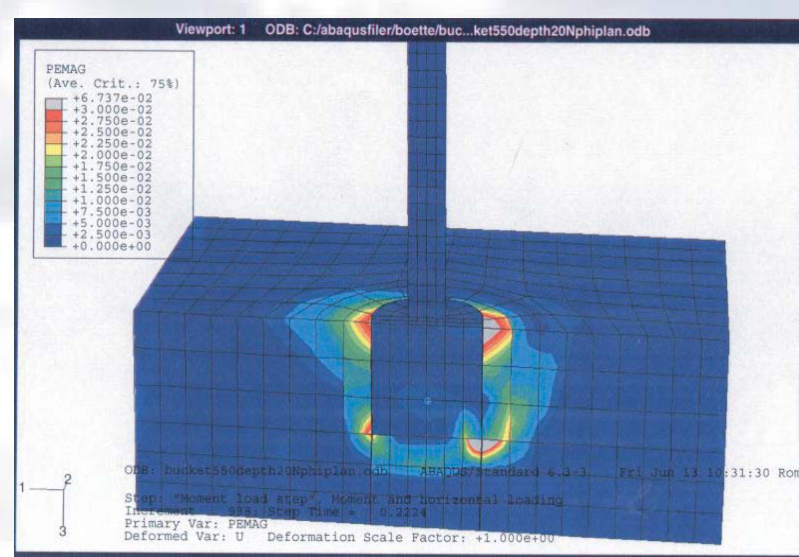
Development of the design procedure

Since the bucket foundation is an innovative foundation, no standard design procedure is available and must be set up. This procedure complies of 3 parts:

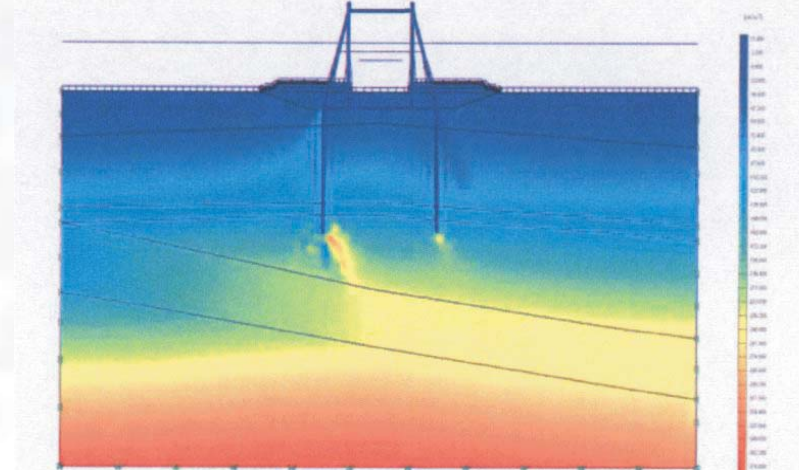
- Design basis describes the wind turbine and the site conditions.
- Conceptual design, demonstrates that the dimensions of the foundation are sufficient to observe the different load sceneries by means of an analytical model. Penetration investigations are carried out based on cone penetration tests (CPT).
- Detailed design, the interactions between the bucket and the soil are investigated. The investigation is carried out by means of the performed model tests and 2D or 3D FE - analysis.



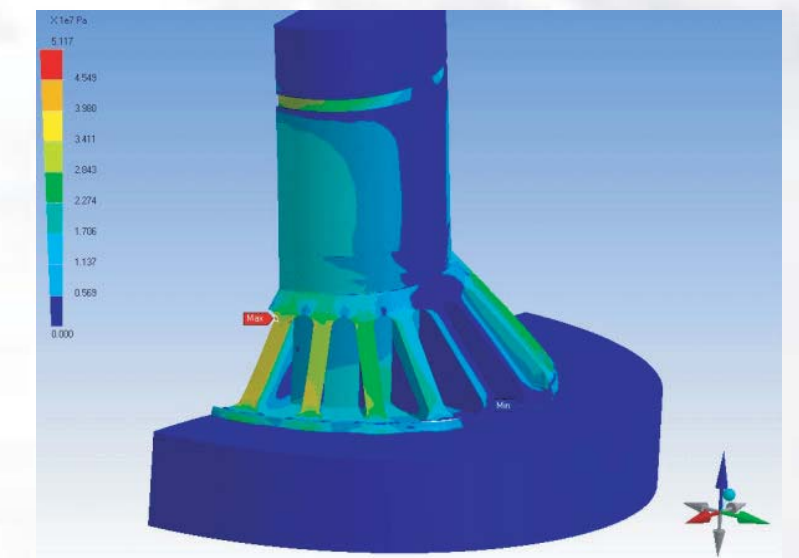
Test bench for buckets 50-400 mm



3D-FEM soil model



2D-FEM soil model



3D-FEM steel structure model

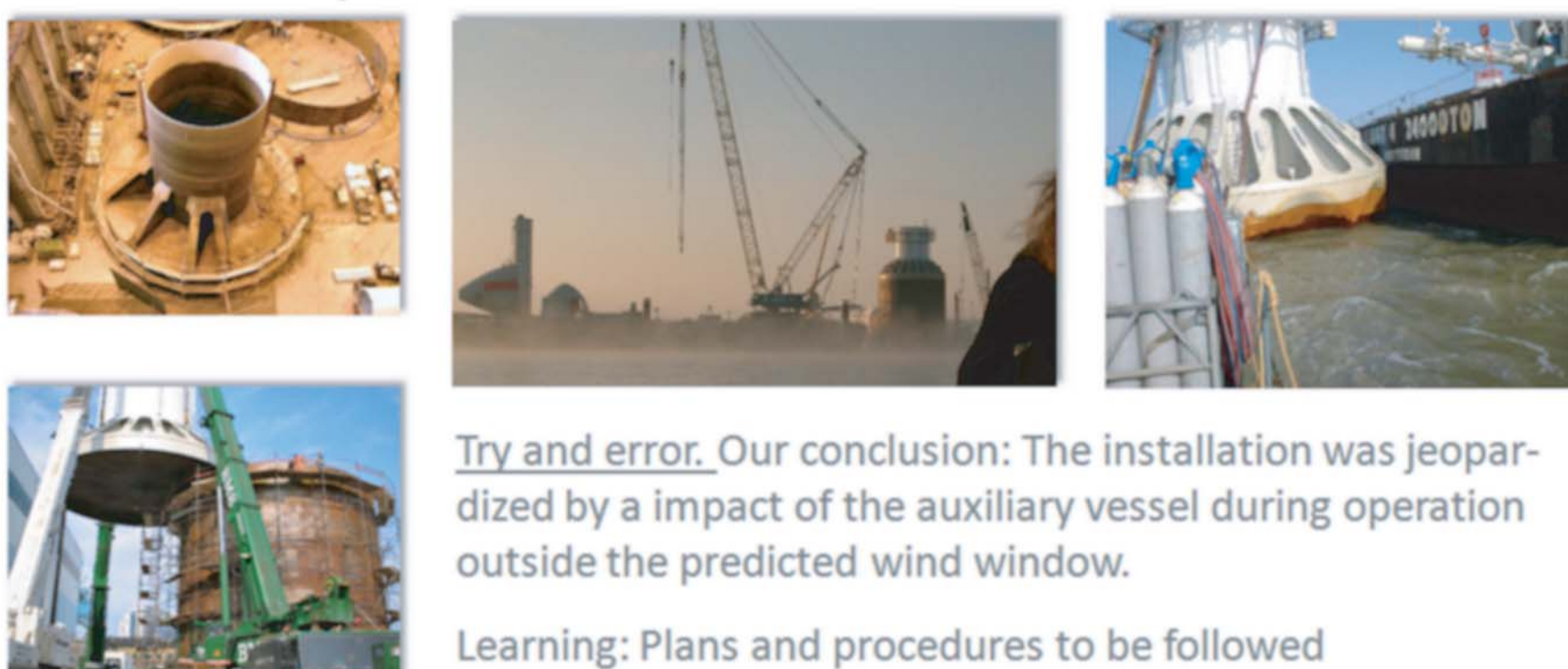
Projects: The prototype for Pos. 1, Frederikshavn

The Ø12x6 m prototype bucket foundation was designed for a Vestas V90 3MW turbine placed on 4 m of water. The design is certified by DNV. The bucket was installed in late 2002 and is in normal operation. The structure/soil interaction has been investigated with sophisticated modal analyse equipment.



Projects: The prototype for Wilhelmshaven E-112

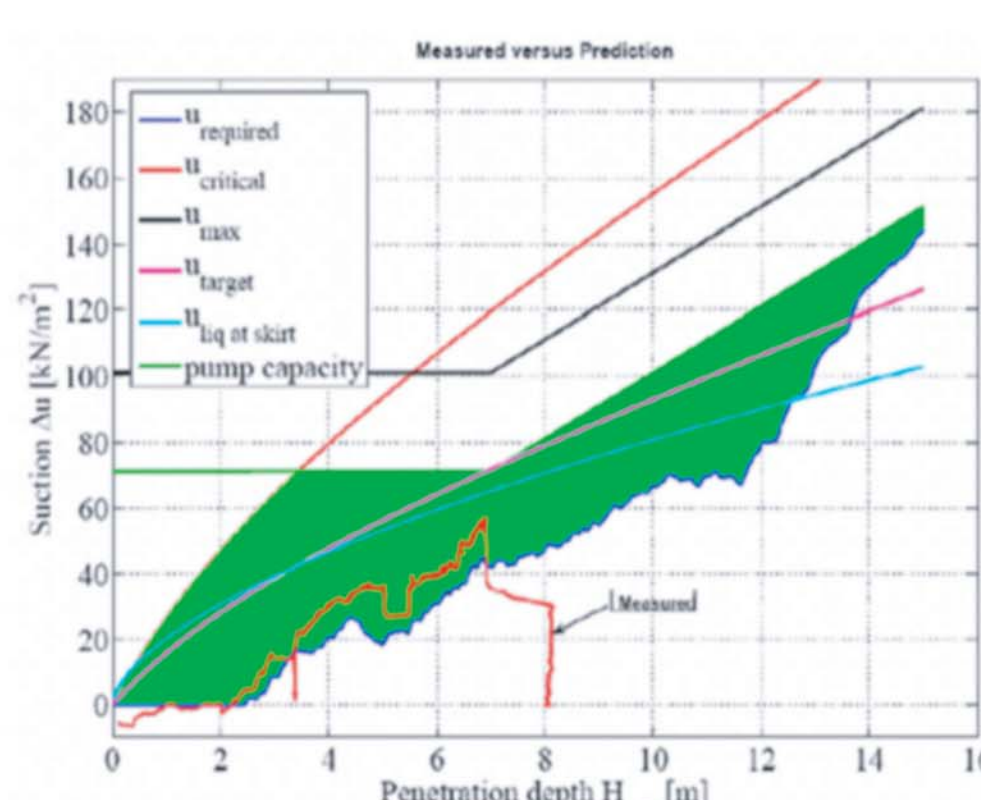
4,5 MW turbine positioned 500 m of the coast outside Hochsiel oil installation
Water depth: 4 m. Load regime: Moment > 300.000 kNm, vertical load > 11000 kN, horizontal load > 5000 kN, foundation weight app. 400 tons.
Installation April 2005.



Try and error. Our conclusion: The installation was jeopardized by a impact of the auxiliary vessel during operation outside the predicted wind window.
Learning: Plans and procedures to be followed

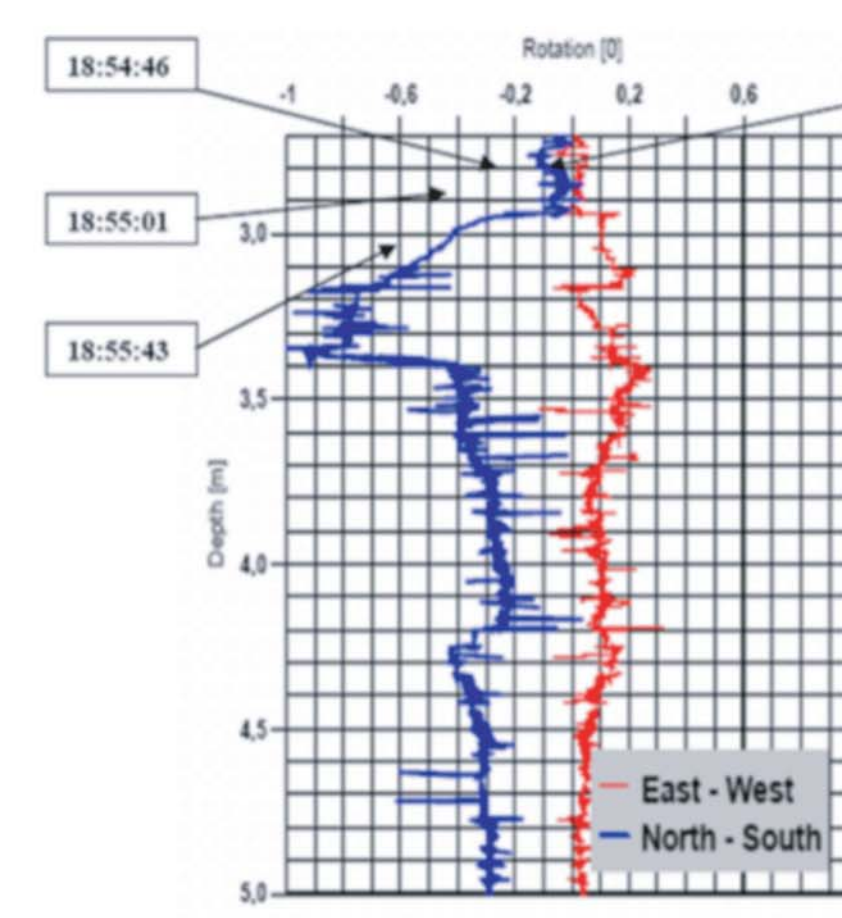
Main incidents

- At 20:27 the penetration was resumed.
- At 5 m penetration a sudden drop in suction pressure was observed.
- At high tide 01:12 and at 6,8 m penetration a sudden drop in suction pressure and rotation of app. 1 degree was observed.
- At 01:35 suction pumps were stopped. Rotation: 4,5 degrees.



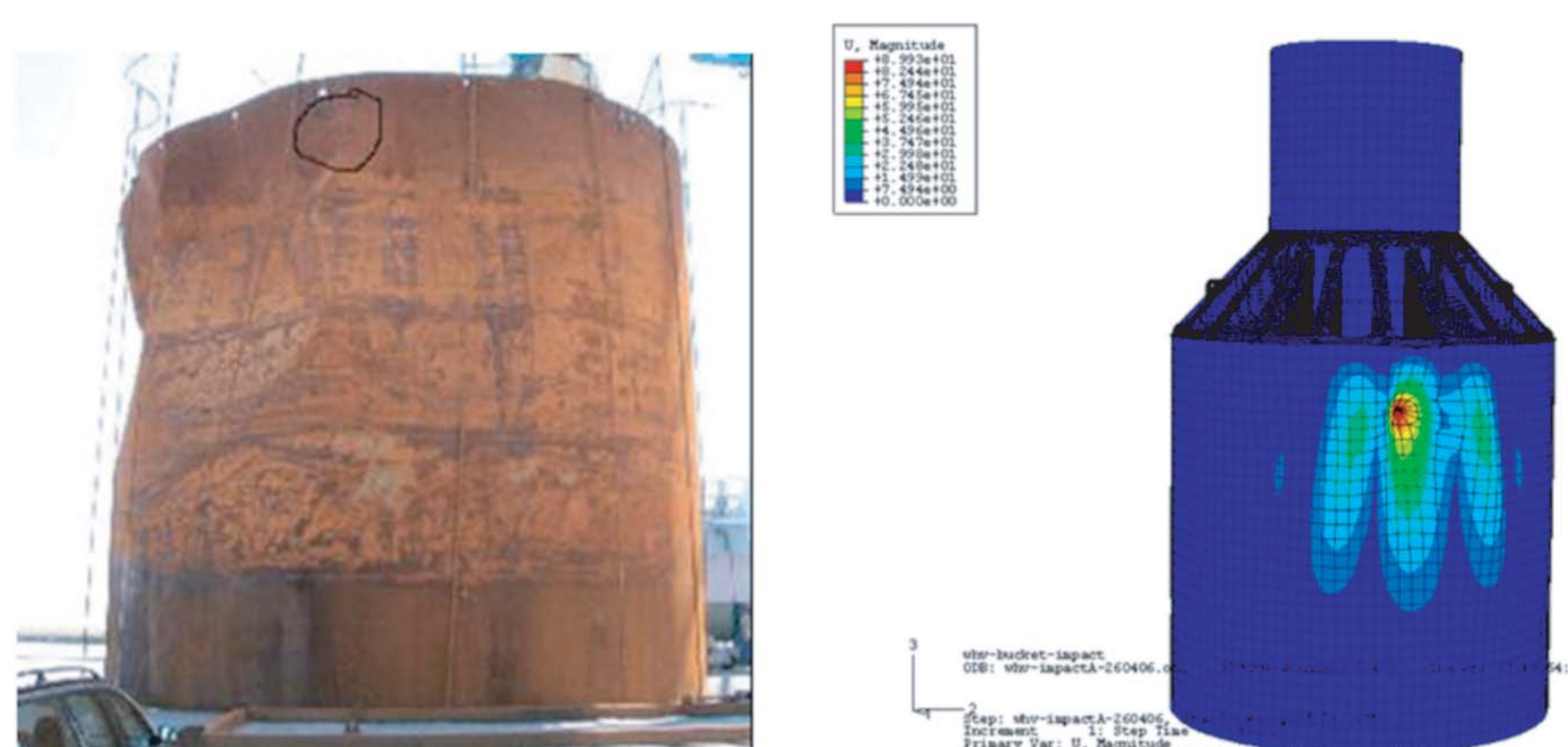
Main incidents

- At 17:37 was the bucket lowered into the seabed at low tide, and suction was applied.
- At 18:54 a sudden rotation was recorded, penetration depth 2,94 m.
- At 20:27 the penetration was resumed.
- At 5 m penetration a sudden drop in suction pressure was observed.



Main conclusion

The initiating factor is most properly the impact of the Giant 4 barge at 3 m penetration leaving a dent of app. 80 mm, coursing instability in skirt.



The bucket concept is developed in a joint venture with:
- MarCon A/S
- Bladt Industries A/S
- MBD Offshore Power A/S
- DONG Energy A/S

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Series of scour protection tests in the laboratory



Development projects

Description	Status
Design methodology for bucket foundations, 2001-2002	✓
Prototype reference bucket Frederikshavn, 2002	✓
Prototype reference bucket, Wilhelmshaven 2005	x
Soil/structure interaction I, integration in FLEX5 / HAWC2	✓
Scour protection in connection with bucket foundations	✓
Dynamic behaviour of suction caissons, Ph. D Thesis 2003 - 2007	✓
Static behaviour of bucket foundations, Ph.D. Thesis 2003-2007	✓
Soil/structure interaction II, large diameter mono piles 2007 - 2009	On going
Physical & numerical modelling of mono piles in silt Ph.D. 2007 - 2010	On going
Offshore installation with Mobile Met Mast bucket foundation, NearshoreLAB, Horns Rev II, UK sites, 2008	On going
Full scale demonstration bucket i NearshoreLAB, 2008/2009	Application
UFC system development, Ph.D. 2008-2010	Planning
High tension concrete composite in support structures, Ph.D. 2008 - 2010	Planning
Scour protection dynamics, Ph.D. 2008-2010	Planning
Advanced probabilistic geotechnical site assessment , 2008 - 2010	Application
Probabilistically modelling of offshore wind farm foundations, 2008 - 2010	Application
Geotechnical site investigation with mobile bucket foundation, 2008	Planning