UNIVERSITY OF OXFORD

PISA – Improved Design of Monopiles

Byron Byrne
Professor of Engineering Science
Presentation on behalf of the PISA Academic Work Group

SUPERGEN WIND GENERAL ASSEMBLY
23 November 2016

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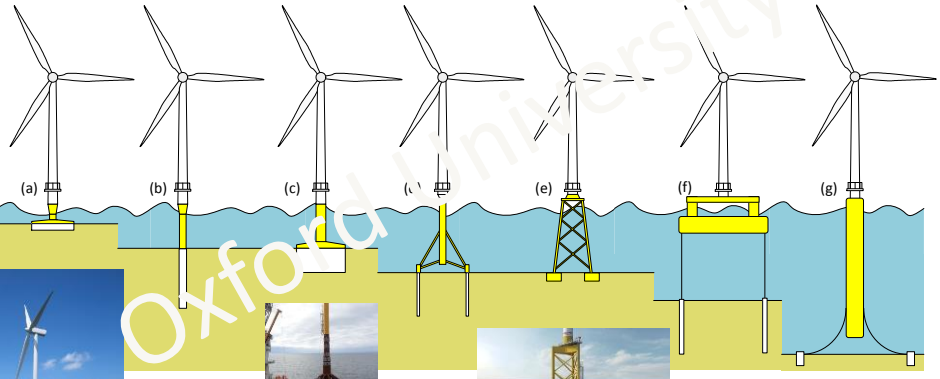
Offshore Wind



Images from various websites

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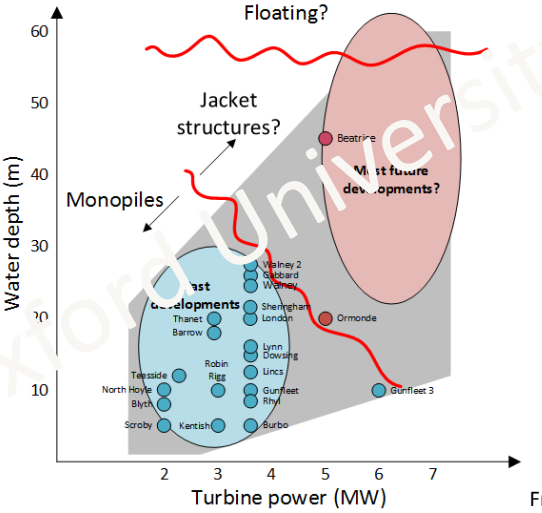
Monopiles

Photos from Dan Kallehave (DONG Energy)

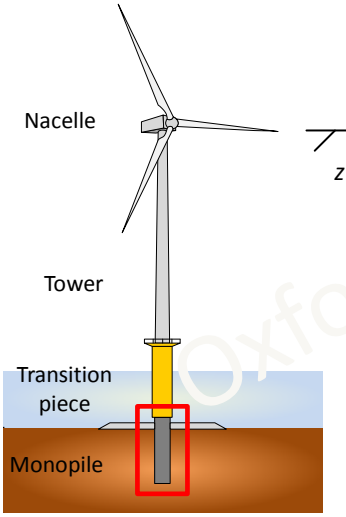
REMS CDT Conference: What is the Limit of the Monopile?

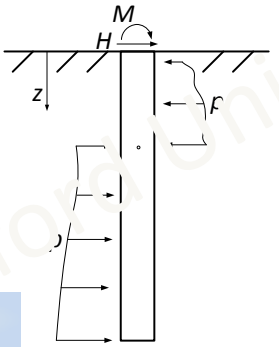


From Guy Houlsby
2014 Rankine Lecture

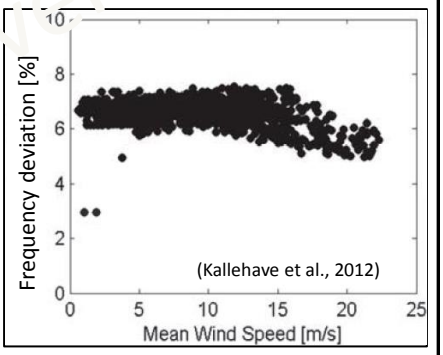
Shortcoming of Existing Design Methods

Offshore Wind + Oil and Gas Design = Design Problems?

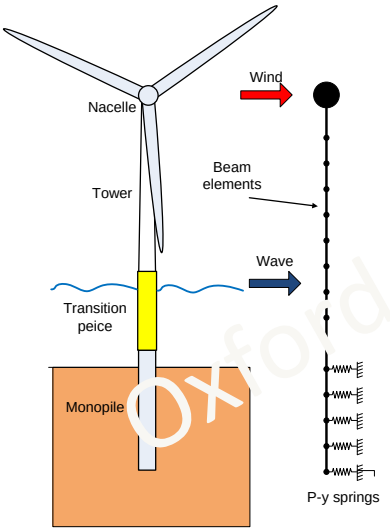


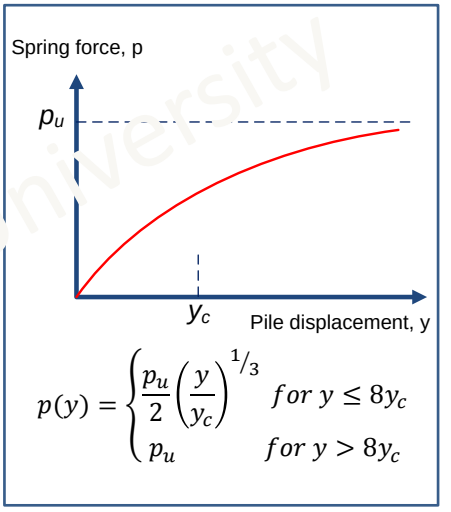


Underestimation of measured frequency



Current Analysis Approach





Organogram

Discretionary Project Steering Committee

CARBON TRUST, SSE, DONG energy, Statoil, IBERDROLA, Statkraft, RWE, VATTENFALL

Non OWA Partners

ALSTOM, EDF energies nouvelles, Van Oord

Academic Work Group

Principal Investigator: Professor Byron Byrne
Professor Guy Houlsby, Dr Harvey Burd, Dr Chris Martin, Dr Ross McAdam
Imperial College London
Professor Richard Jardine, Professor David Potts, Professor Lidija Zdravkovic, Dr David Taborda
Dr Ken Gavin, Dr Paul Doherty, Dr David Igoe

Lead Partner

DONG energy
Project Manager: Jesper Skov Gretlund
Technical Manager: Miguel Pacheco Andrade

Project Partner Technical Experts

Independent Technical Review Panel

NTNU
Chairman: Professor Gudmund Eiksund
Liv Hamre, DNV
Dr Fabian Kirsch, BAM Bundesanstalt für Materialforschung und -prüfung
Tim Camp, GL Garrad Hassan
Professor Werner Rucker

Assisting Consultants

ORDTEK — UXO Consultant
bre — Testing Assistance
ATKINS — Testing Management
Advanced Numerical Modelling
PARSONS BRINCKERHOFF — Structural Designer and SI Supervision

Testing Contractors

ESG Environmental Scientifics Group — Principal Testing Contractor
NLMK DanSteel A/S — Steel Supplier
BLADT INDUSTRIES — Pile Fabricator
marmota — Fibre Optic Supplier
DAWSON CONSTRUCTION PLANT LTD — Pile Installation
SANGWIN — Site Preparation
GEOLABS — Laboratory Testing
IN SITU SITE INVESTIGATION — CPT Investigation
CONCEPT — Site Investigation

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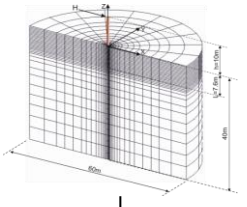
Project Overview – 2.5 years and £3.5m

3D FE

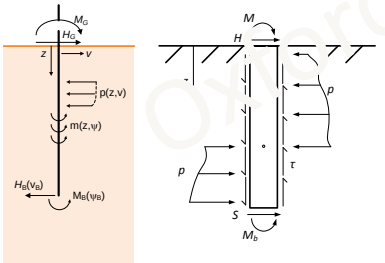


Design

Validate

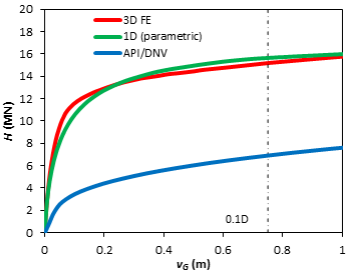
Field Tests

Simplified 1D Model



Apply

Accurate Response Prediction



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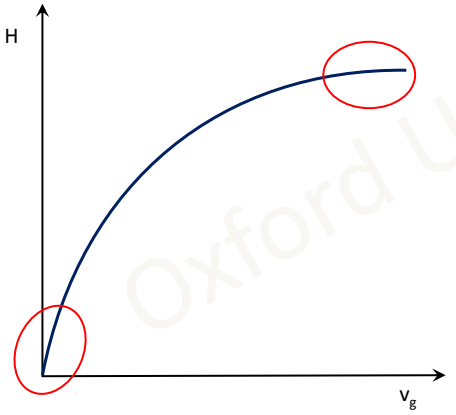
Focus of Modelling

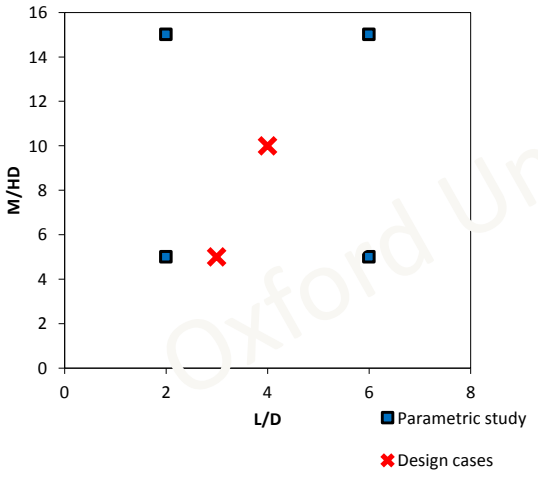
- Monotonic loading only
- Two materials - stiff over-consolidated clay till and dense sand

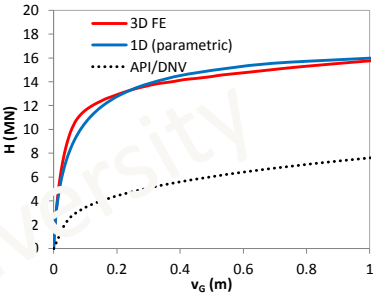


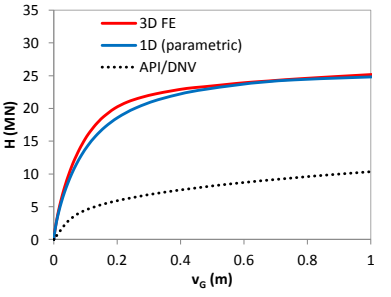
For realistic numerical prediction of pile response:

- initial loading:
  - small strain soil behaviour
- ultimate load:
  - soil conditions at failure

How Good?

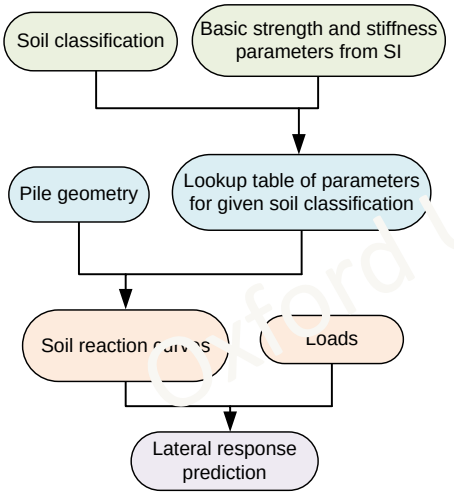




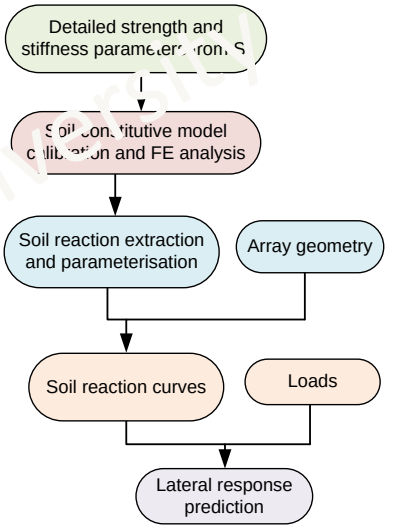


Overview of PISA Design Approach

Rule-based method



Numerical-based method

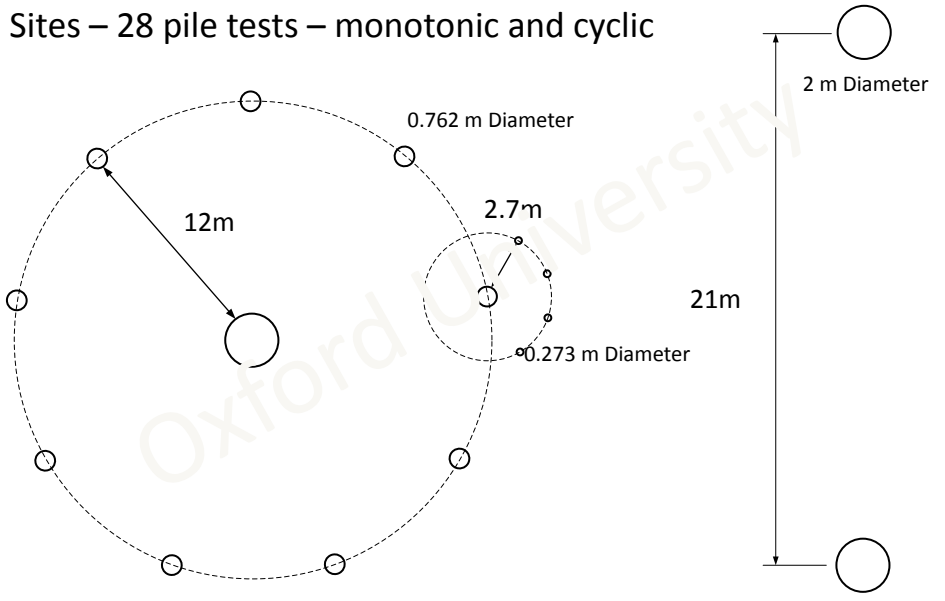


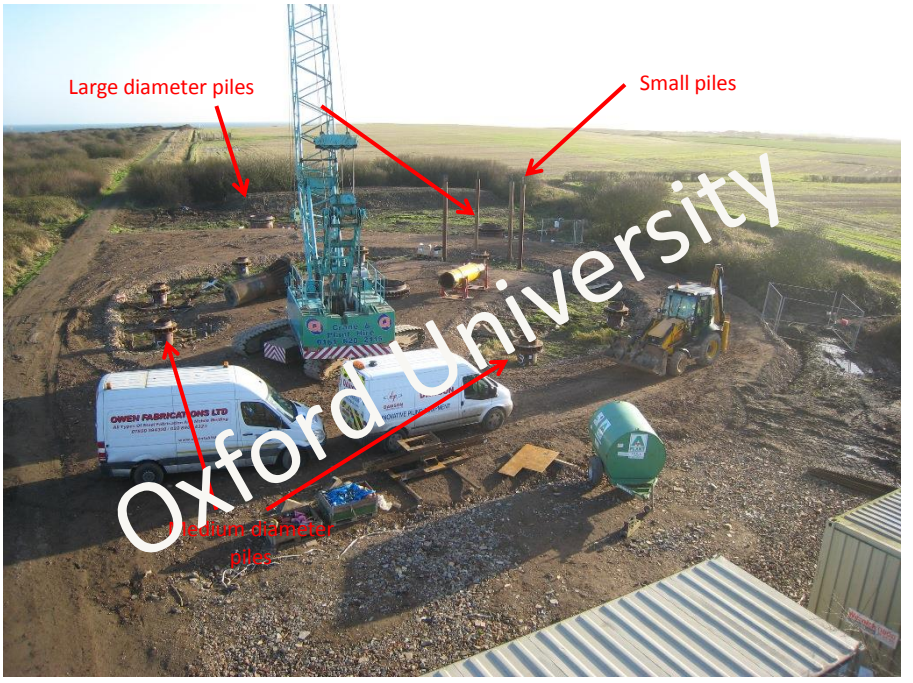
Site Selection

- Representative soil conditions
  - Cowden – stiff clay site
  - Dunkirk – dense sand site
- Existing characterisation used as a basis for FE modelling
- Additional in-situ and laboratory based characterisation completed

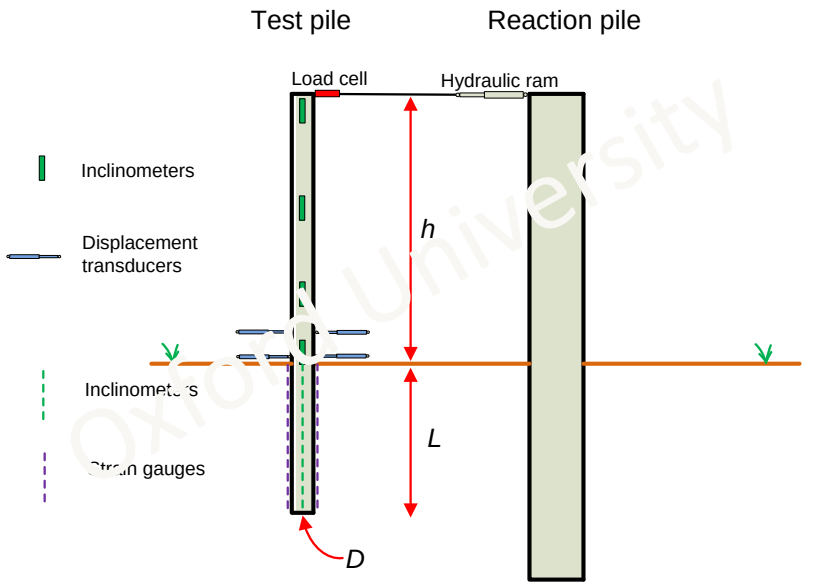
Field Test Program - Layout

2 Sites – 28 pile tests – monotonic and cyclic

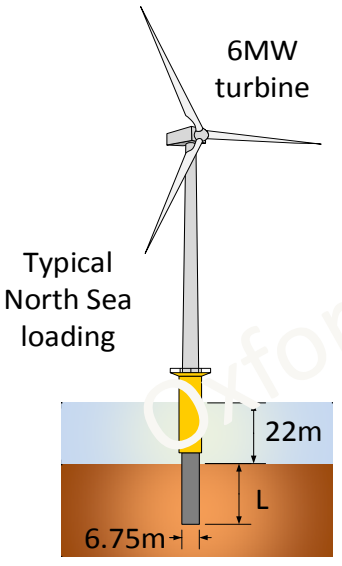




Test Arrangement

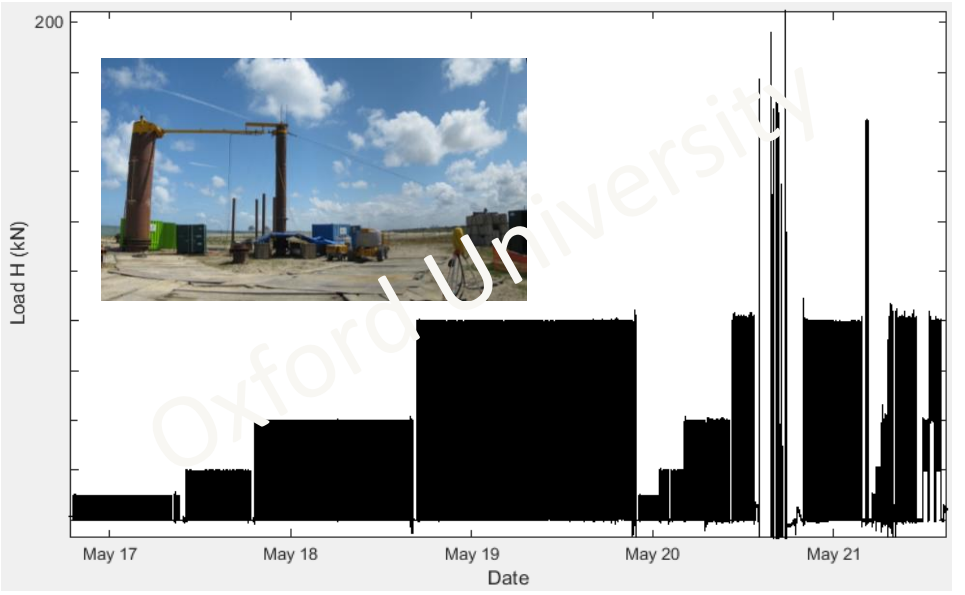


Potential Industry Impact



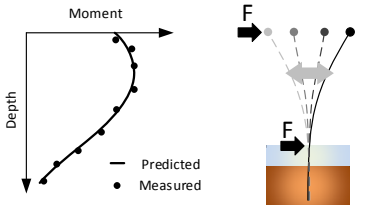
Design method	Pile length (m)	Pile weight (tonnes)
"*p-y*" approach	31.25	309
PISA approach	20.0	198

Cyclic Testing

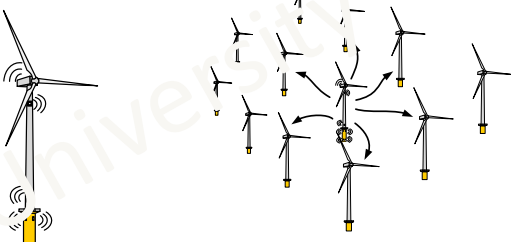


Supergen Wind Hub Flexible Funding Pilot Project
Oxford University / Durham University

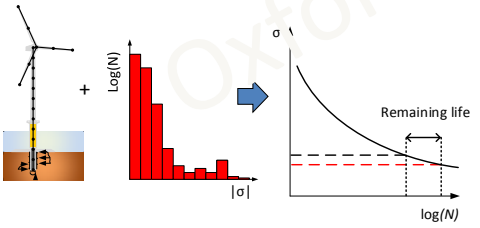
Design Validation



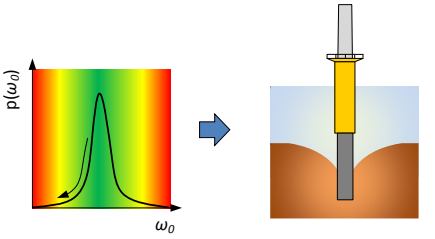
Distributed Approach



Lifetime Assessment



Fault detection



Concluding Remarks

- Next generation monopile foundations will be large
  - Deeper water
  - Larger turbines
- New design methods needed for optimisation
  - Developed from numerical analysis
  - Benchmarked against field testing
  - Monotonic and cyclic loading
  - Results here suggest reduction of steel by 30% compared with the API / DNV methodology leading to significant savings in installation costs
  - Final report distributed to Partners in May 2016
  - Further phases of work currently ongoing
- Wider dissemination after end of confidentiality period
- PISA – A great example of industry and academia working together to solve important technical challenges