

# Rapporteur's Summary

Richard Jardine

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# 50 years of offshore geotechnics, 38 years of OSIG

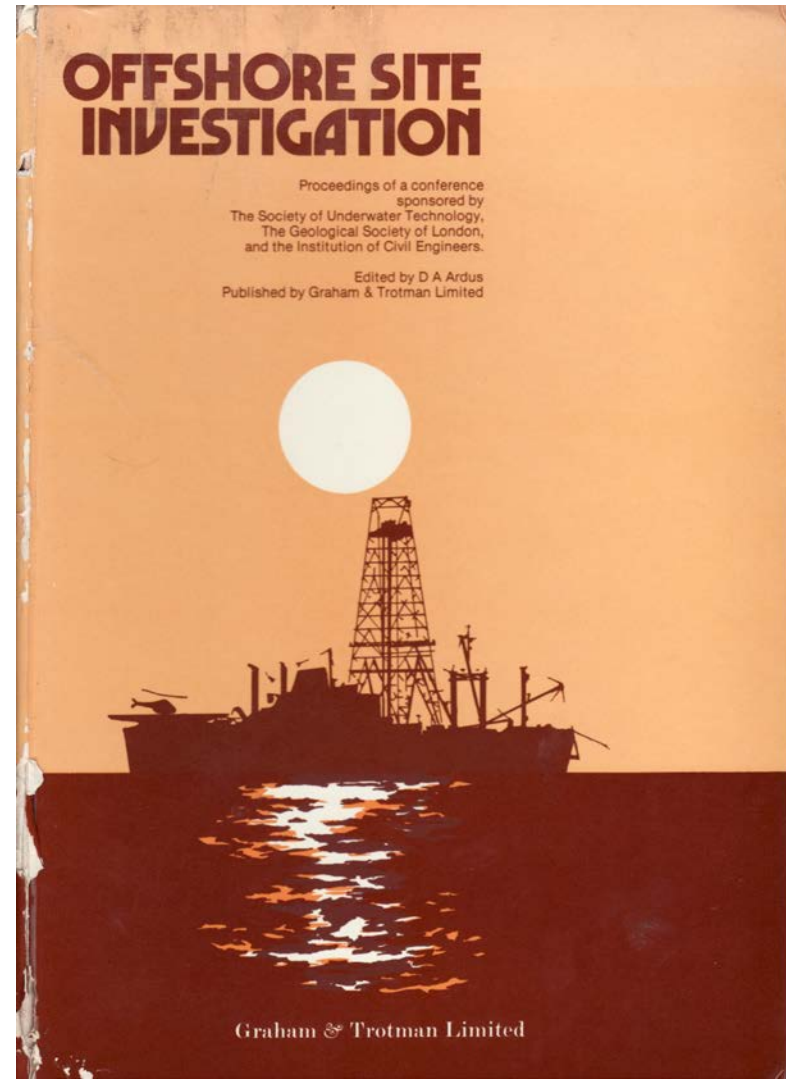
1<sup>st</sup> in 1979, SUT with Geological Society of  
London & UK Institution of Civil Engineers

Edited by Denis Arduş

Geology & Site Investigation techniques

Difficult discussions on emerging technologies

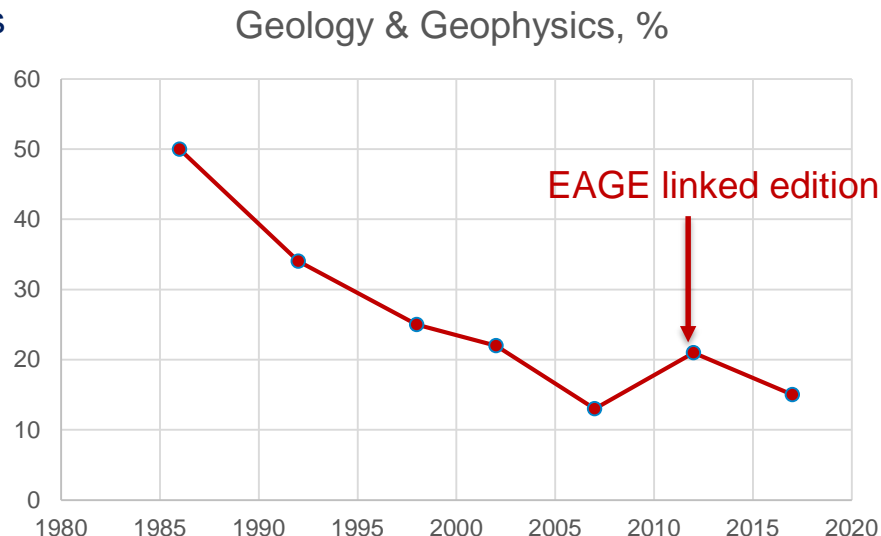
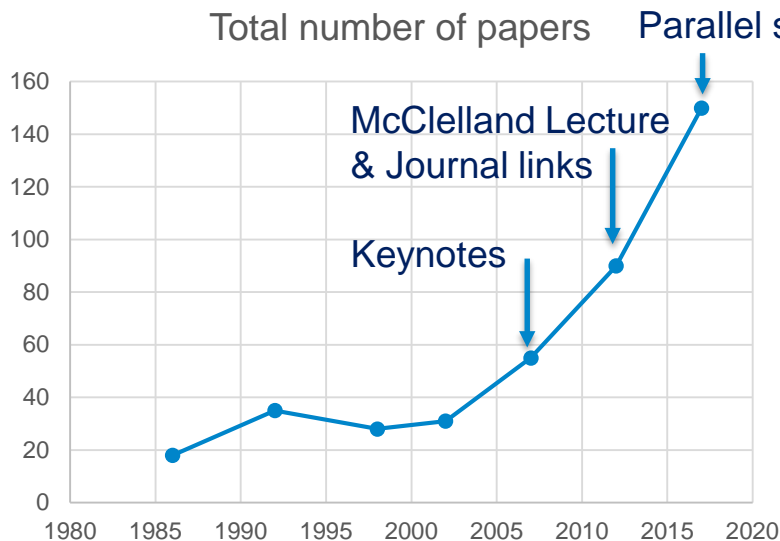
Included first Rapporteur's Summary



# OSIG trends over the years:

## Good news

And one undesirable trend that has stabilised



# Proceedings & Rapporteurs: 1986 to 2012



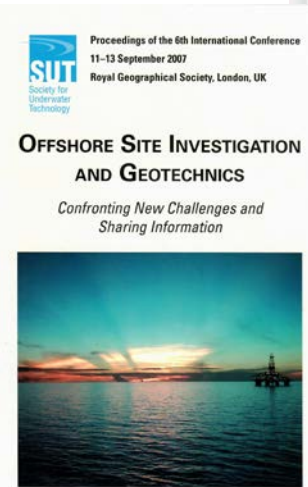
Peter Wroth



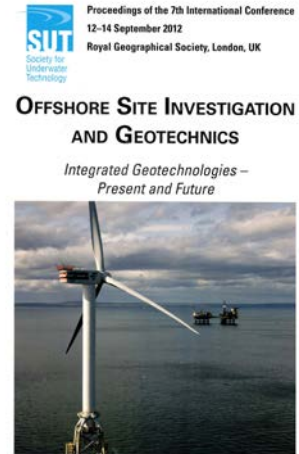
John Burland



Offshore Site Investigation  
And Geotechnics  
Diversity and Sustainability



Malcolm Bolton



Sacha Puzrin

## OFFSHORE SITE INVESTIGATION AND GEOTECHNICS

***SMARTER SOLUTIONS FOR  
FUTURE OFFSHORE DEVELOPMENTS***

**VOLUME 1**



1<sup>st</sup> valuable lesson from the last 38 years:

Don't take Rapporteur's summaries too seriously,  
especially this one!

# 150 papers in two OSIG 2017 volumes plus EAGE Near Surface Geophysics

## Offshore Site investigations

Geology and geohazards

Geophysics, EAGE session

Integration

SI techniques

Advanced soil characterisation

Case histories

## Offshore Geotechnical Engineering

Suction installed foundations

Pile design & installation

Shallow foundations

Pipelines

Mooring systems

Windturbine foundations

Design studies & case histories

12 plenary and 3 parallel sessions

1320 pages of proceedings, plus

100 in Near Surface Geophysics

So is the Rapporteur's job now mission impossible?

Try to give personal view based on 'first impressions'

Start with the 'main attraction' – **McClelland Lecture**

## Alan Young's McClelland Lecture

*'Applying Bramlette McClelland's six principles of Integration'*

Interdisciplinary team

High resolution geophysics

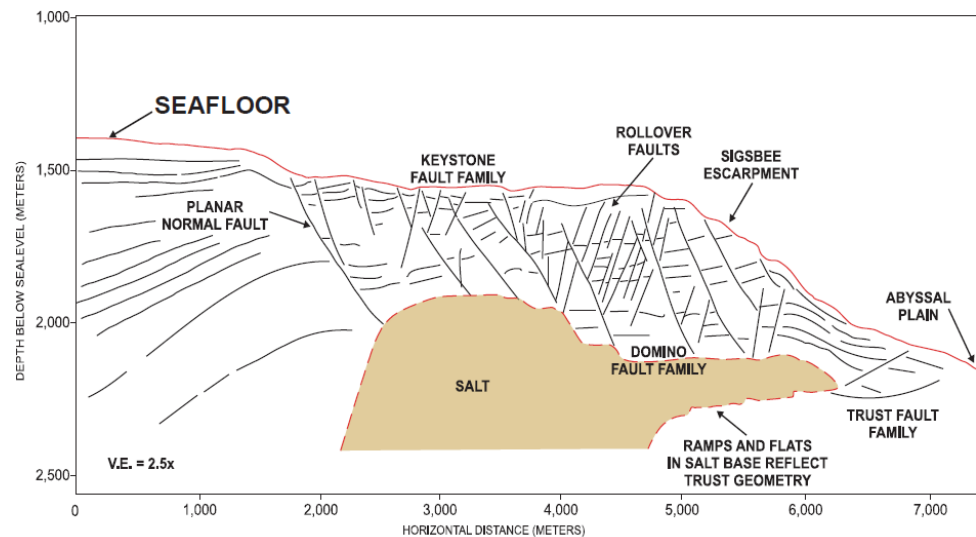
In-situ testing & high quality samples

Use to identify sample disturbance

Calibrate design against field & model tests

Integrate geology & geotechnics to constrain site development risks

## Geology, Geohazards and Integration



*Figure 19: Seismic profile illustrating salt/fault interaction across Sigsbee Escarpment (Young and Kasch, 2011) ©*



## More on Site Investigations

Steve Thomas' keynote

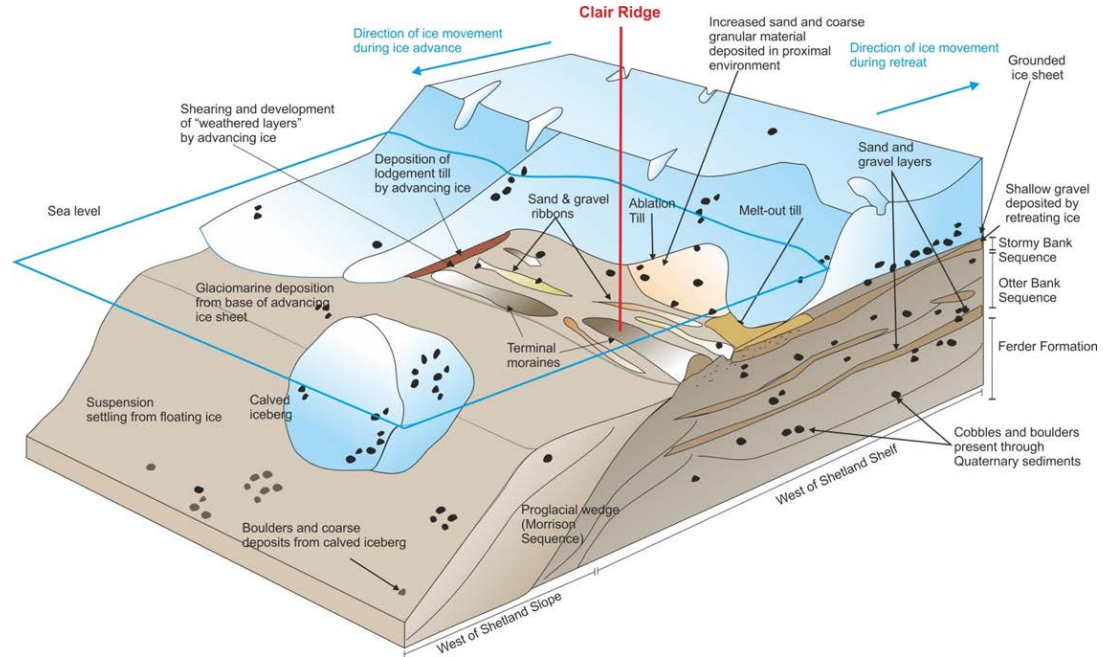
*Phased and integrated data interpretation approach to site characterisation*

Rich in experience & examples, emphasises role of multi-disciplinary workshops & GIS as way forward

Salutes work of Kerry Campbell, Mike Sweeney and Trevor Evans at BP

Clair Ridge paper by Hampson et al offers example from Thomas' casebook that applies McClelland's 'six principles'

## Geology, Geohazards and Integration



Clair Ridge conceptual ground model  
Hampson et al, Fig 2

Eight Conference papers, from Gulf of Mexico to North and Timor Seas

### EAGE, Near Surface Geophysics session

An Ultra-High-Resolution 3D marine seismic system for detailed site investigation; Monrigal et al

Advanced processing for UHR3D shallow marine seismic surveys; Duarte et al

Tuning, interference and false shallow gas signatures in geohazard interpretations: beyond the “ $\lambda/4$ ” rule; Barrett et al

A petrophysical approach to the investigation of shallow marine geology; Buckley & L Cottee

State of the art remote characterisation of shallow marine sediments: the road to a fully integrated solution; Vardy et al

How understanding past landscapes might inform present-day site investigations: a case study from Dogger Bank, southern central North sea; Cotterill et al

Identifying and mitigating against potential seafloor and shallow drilling hazards at a complex Gulf of Mexico deepwater site using HR3D seismic and AUV data; Kassarie et al

Direct monitoring of active geohazards: emerging geophysical tools for deepwater assessments; Clare & Vardy

## Site Investigation Techniques

## Conference Papers

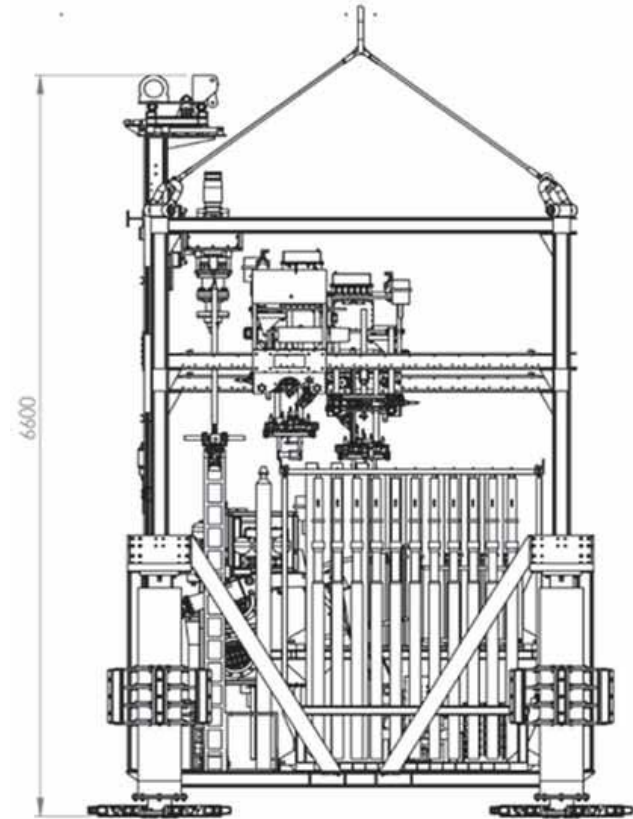
16 session papers and others in 'design studies' & 'case history' sessions

From optimising SI for windfarms to new X-ray logging techniques

Effects of gas on sampling disturbance to analysis of pressuremeter tests in chalk

CPT standards to laboratory techniques for sands & clays

And new drilling equipment



*Automation and control in a submarine drill rig: Arriaga et al*

## Site Investigations

Ten session papers, many more related articles in SI and other sessions

Need to improve load-displacement modelling

And address cyclic loading, following OSIG 2012, TC-209 Paris 2013 & ISFOG 2015 keynotes & McClelland Lecture

Six papers on modelling of sands: essential to capture non-linear stiffness & shear strength dilatancy relationships

And also new work on soft rocks

## Advanced soil characterisation

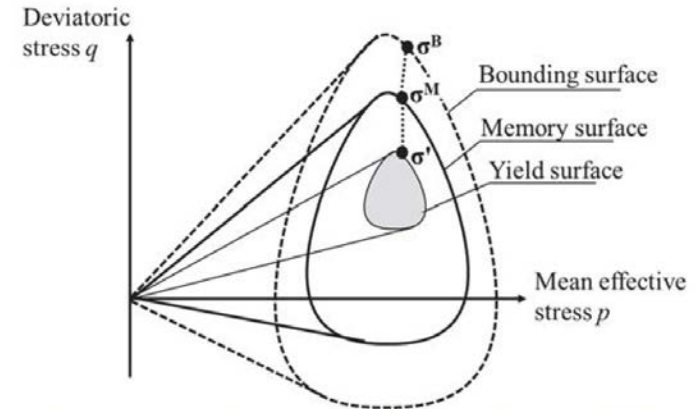


Figure 1: Schematic representation of the Memory Surface Hardening model

Corti and Diambra

## Moving to Geotechnical Engineering

11 session papers and other related articles

Layered soils, sands & clays

Cyclic, seismic and tension loading

Six Degree of Freedom loading

Carbonate soils

Caisson extraction & decommissioning

FE analysis, centrifuge & installation studies

Seepage & critical suctions in sands

## Suction installed foundations

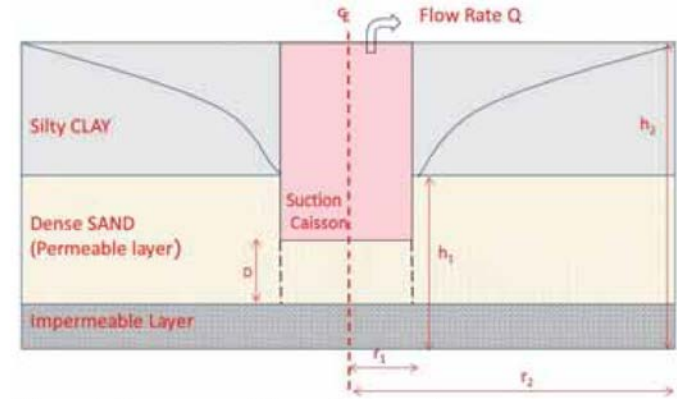
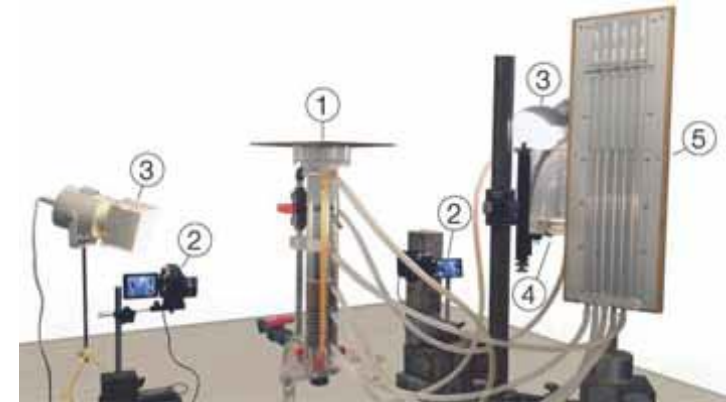


Figure 6: Seepage conditions during suction caisson installation in layered soils Panayides et al



LUFT test set-up; Panagoulas et al

16 session papers plus multiple articles in other sessions

Three piling keynotes

Jeanjean et al: Lateral loading: monotonic p-y curves in clay

Byrne et al; PISA JIP on monopiles

**Lehane et al keynote:** unified data base JIP for axial capacity for sands & clays

Axial design method uncertainty; UWA, NGI, Imperial College & Fugro team

## Lehane et al keynote

Strict criteria: 71 from 287 sand tests, 49 of 300 in clay

Not included: silts, silty, calcareous or mica sands

‘Problem’ cases & lack of necessary SI data for clays

Clear CPT method advantages in sand

Confirm independent ZJU-ICL study, Yang et al 2015-17

20+ years of use, adopt as main API/ISO method?

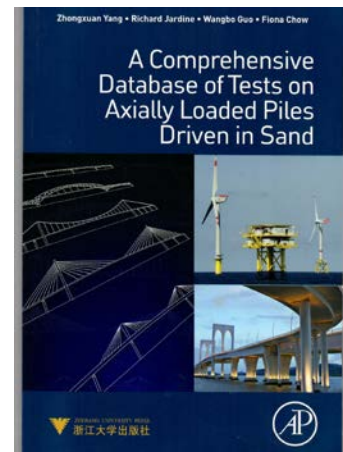
Clay results depend critically on SI, advantages in CPT methods. **Correct SI essential with ICP-05**

Set-up & age important in sands & clays

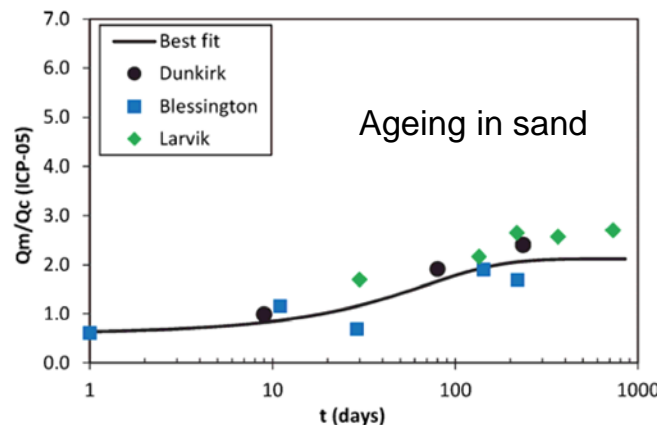
Rarely checked, often incomplete in clay tests

End of driving  $Q_{\text{shaft}}$  often far lower than service capacity

## Axial pile design reliability



ZJU-ICL study: Yang et al





## Lehane et al keynote: final para..

Finally, it should be remembered that site specific offshore pile load testing can provide a direct means of improving design reliability in soil types for which capacity prediction is subject to excessive uncertainty

## Barbosa et al OSIG update

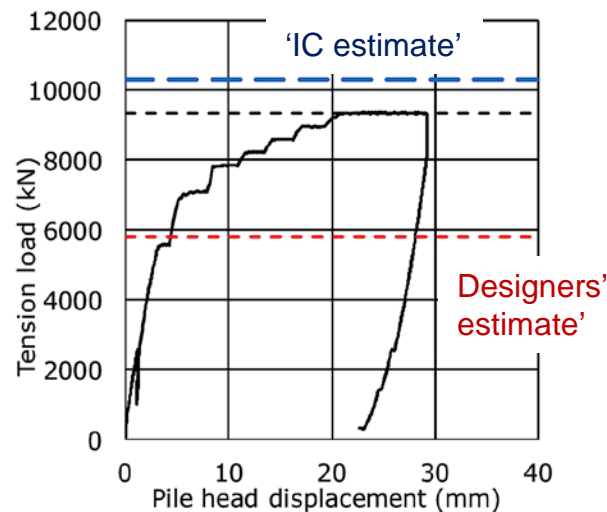
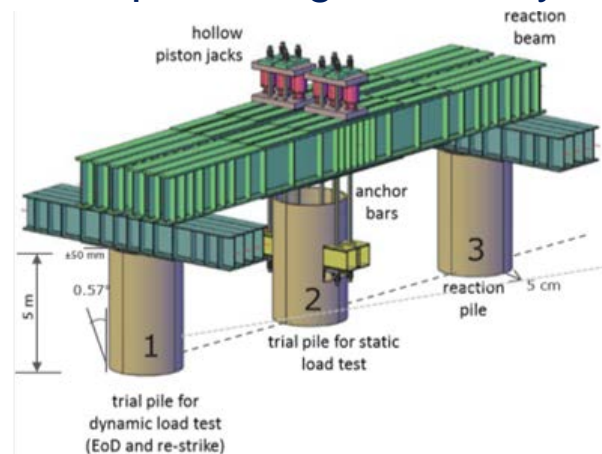
Six 1.37m OD, up to 30m long piles driven in chalk & glacial till, aged for  $\approx 80$  days before testing

Static and dynamic EoD and aged re-strike tests  
Cost-effective for 70 WTG Wikingen project

Further research JIP & production piling monitoring

Chalk: OSIG papers, 2018 BGA & ALPACA JIP

## Axial pile design reliability





## Need to improve load-displacement predictions

Little change since routine t-z, p-y and elastic group interaction analyses since 1970s

Despite case histories showing inadequacies of routine approach in N Sea soils

Hutton TLP & Magnus monitoring projects  
Large Diameter Pile test programme  
Shearwater platform monitoring

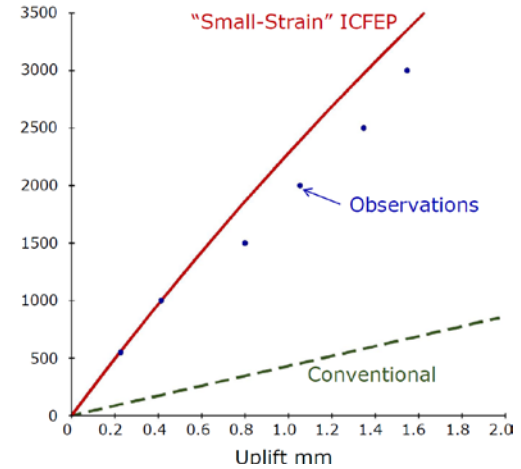
And benefits of moving to more advanced 'stress path' soil testing & analysis

Critical impact on structural fatigue & WTGs

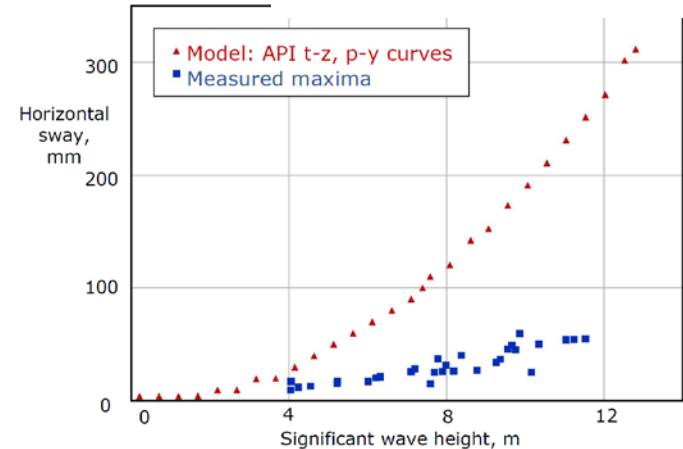
Jardine & Potts (1988), (1993), Clarke (1993), Hunt (1999)

Group load  
tonnes

Axial movement: Hutton TLP



Shearwater: horizontal sway



## Jeanjean et al keynote

Reviews history of p-y rules, recognises limitations & problems

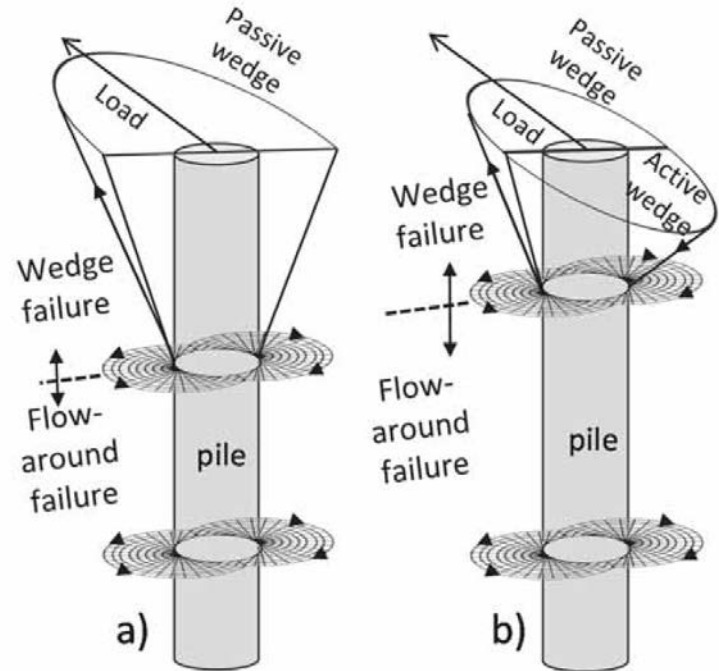
Updates shallow & flow-around mechanisms, emphasises importance of gapping & need to improve displacement predictions

Anisotropy & rate effects; p-y shapes linked to DSS test curves. Normalisation & curve fitting supported by 2D non-linear FE

Monotonic procedure checked against field & centrifuge tests

Application to monopiles?

## Lateral pile loading p-y curves for clays



for a) gapping and b) no gapping condition

Other Jeanjean et al OSIG papers on p-y framework for cyclic loading & layered profiles

## Byrne et al keynote

Large JIP project; led by DONG Energy & partners with Academic Work Group

Addressed need for better monopile design

Generic procedure, demonstrated for N Sea dense sands & stiff glacial clay till

Theoretical studies

Advanced lab and in-situ SI

Advanced 3-D numerical analysis

Simple 4-component 'Winkler' models

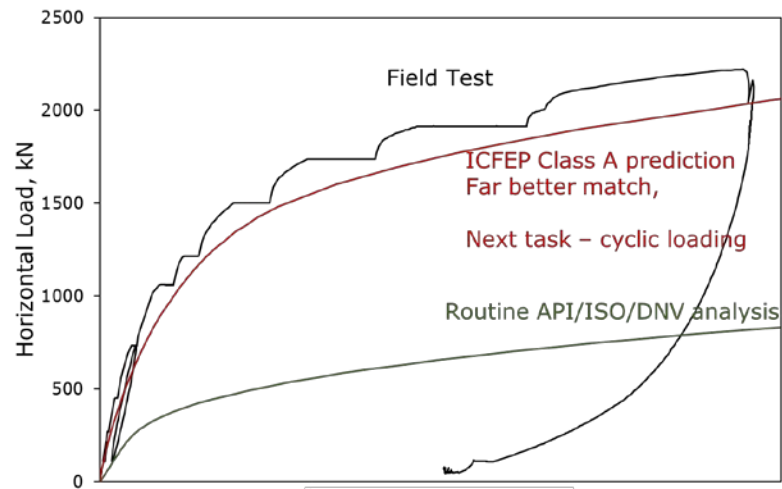
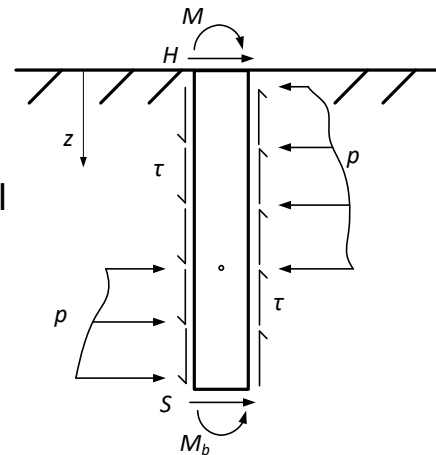
Multiple field tests at Cowden & Dunkirk

PISA approach being applied in WTG projects, offering substantial benefits

## PISA JIP: monopiles in sands & clays

4- component simplified model

And 2m OD Cowden test versus p-y & advanced FE



Also 16 session papers and many others on piling

Jackets, caissons & monopiles: sands, clays & soft rocks

Static, cyclic, seismic, axial, lateral, moment & torsion loads

Driving resistance, set-up and ageing

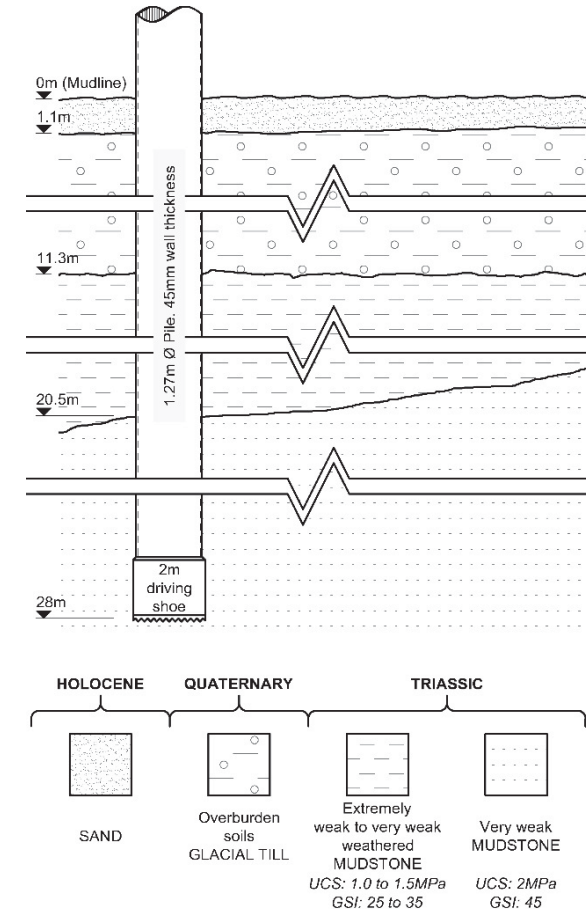
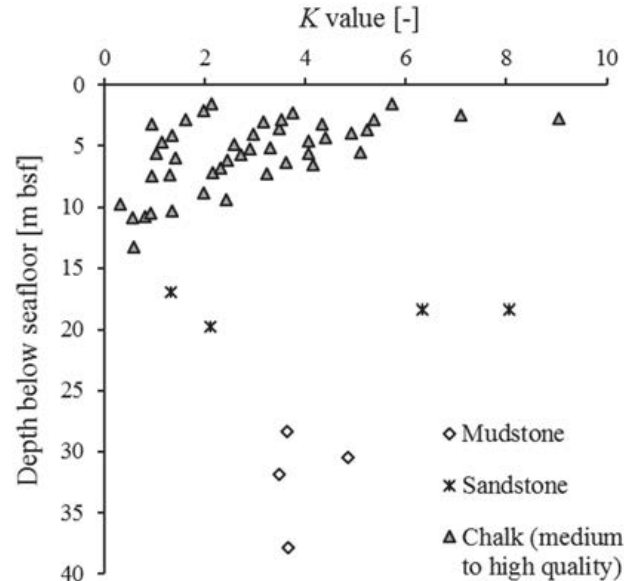
Full scale field testing

Great uncertainty in rock

New research focus

Examples: Terente et al

Also, Sultaniya et al, Duhrkop et al  
Buckley et al & others



## Geotechnical Engineering

## Windturbine foundations

PISA keynote by Byrne et al

14 session papers plus related papers

Wider range foundation types & ground conditions

Deficiencies of p-y design methods for monopiles

Numerical methods & advanced characterisation

Cyclic loading, at least 5 papers

SOLCYP process, quoted by Rattley et al

## Other Geotechnical Engineering

14 session papers with articles in other sessions

Consolidation effects

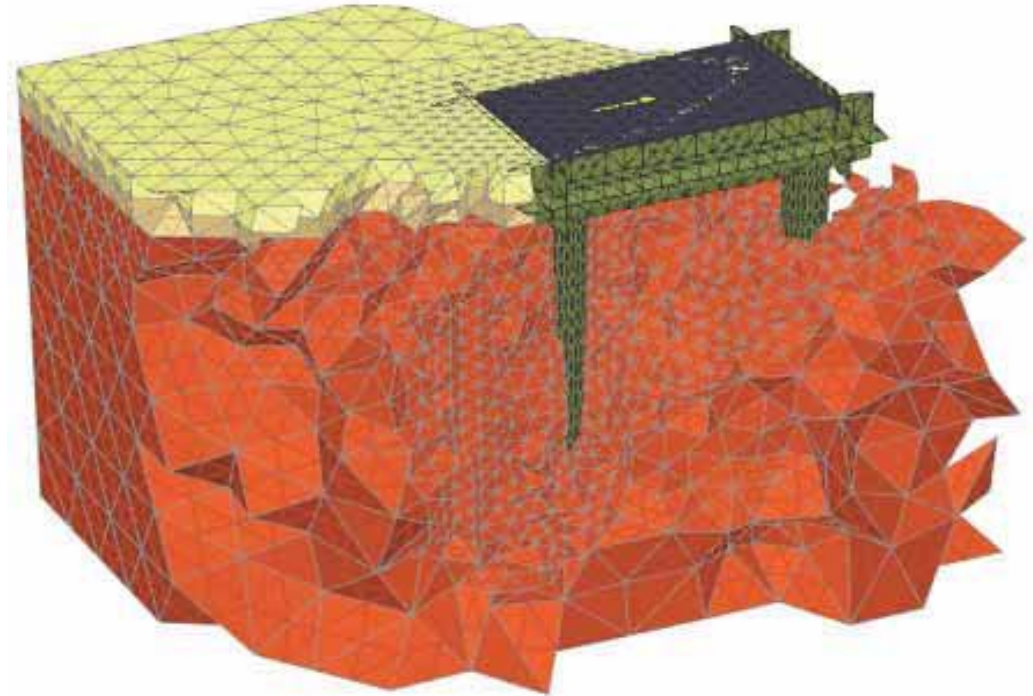
Multi dimensional loading

Whole life analysis, retrieval and decommissioning

Full scale measurements for retrieval forces

Hybrid foundations

## Shallow foundations



FE mesh for hybrid foundation, Wallerand et al

## More Geotechnical Engineering

JK Dix keynote on thermal lifetime performance of marine HV cables

11 pipeline session papers

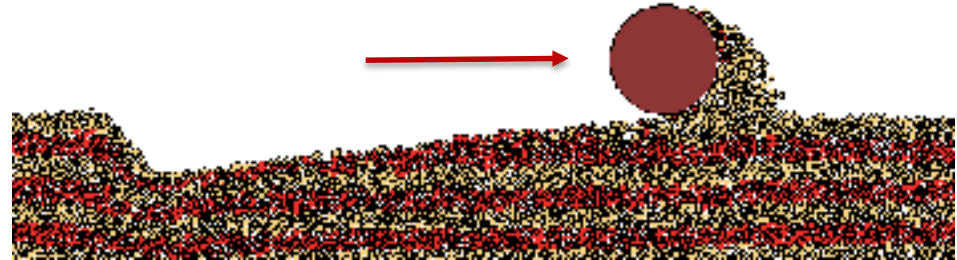
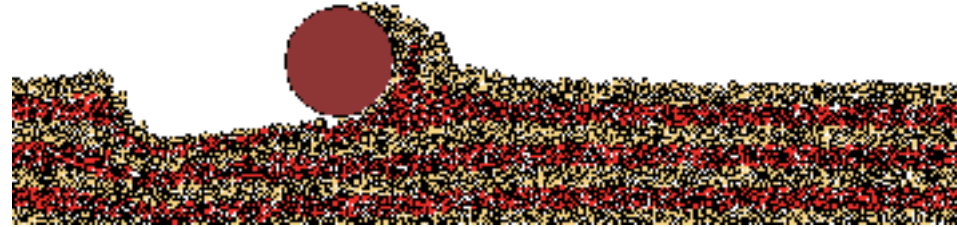
Through life analysis, with 'critical state' framework for clays

Numerical analysis, including DEM treatment of berm formation in sands

Floatation & free span conditions

Burial, ploughs, risks, rock & sand berms

## Pipelines



DEM analysis & experiments by Zhao et al



# Geotechnical Engineering

## Mooring systems

13 session papers and other related papers

Helical pile anchors

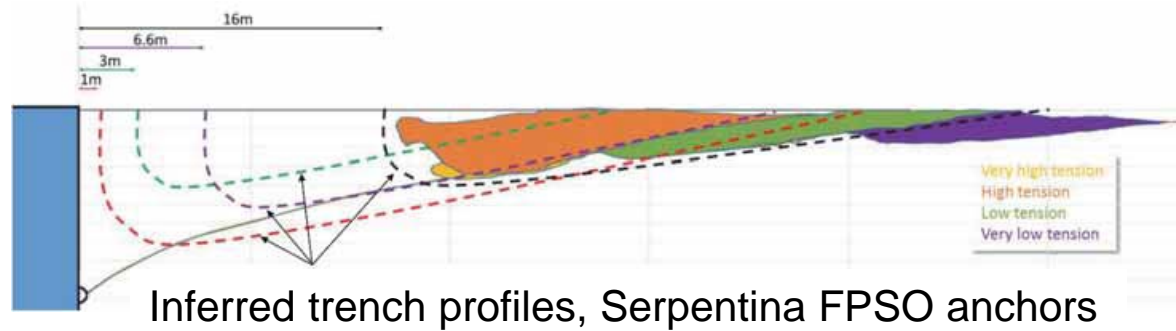
Dynamically installed anchors

Plate anchors

Jack ups & their spudcans, with City Conference to follow soon

And anchor cable chain trenches

**Oil & Gas Industry's most pressing current geo-challenge?**



ROV image of cable trench, Sassi et al



## 150+ OSIG papers

### Offshore Site investigations

Geology and geohazards

Geophysics, EAGE session

Integration

SI techniques

Advanced soil characterisation

Case histories

### Offshore Geotechnical Engineering

Suction installed foundations

Pile design & installation

Shallow foundations

Pipelines

Mooring systems

Windturbine foundations

Design studies & case histories

Any significant final overall messages?

Many excellent papers & contributions at successful OSIG 2017

Plan for Houston ISFOG (and BGA's Chalk 2018 at Imperial College)

Don't take Rapporteur's summaries too seriously

Have a safe trip home or onto ICSMGE in Seoul