
GDG
GAVIN & DOHERTY
GEOSOLUTIONS

# Offshore Wind Foundations

leanwind

## Amsterdam, November 2017

Presenter: Dr Paul Doherty

*Managing Director– Gavin and Doherty Geosolutions Ltd. (GDG)*

Project supported within the Ocean of Tomorrow call of the European Commission Seventh Framework Programme

# Introduction

## Gavin & Doherty Geosolutions

Gavin & Doherty Geosolutions Ltd. (GDG) is a specialist geotechnical engineering consultancy, providing innovative geotechnical solutions across a broad range of civil engineering sectors. Our geotechnical engineers provide services to both the domestic and international markets including concept design, detailed design, in-situ monitoring and general geotechnical advice.

We moved to a new office! Address:
**Unit A2, Nutgrove Office Park**
**Rathfarnham, Dublin 14, D14 X627**

**Delivering the most progressive, reliable, and efficient geotechnical designs across a wide variety of subjects and situations**

Infrastructure

Offshore

Structures

Renewables

Research & Development

# Introduction

➢ LEANWIND Work Package 2

**Construction, Deployment and Decommissioning**

**Work Package Leader: GDG**

**Main Focus**

➢ Cost and time optimisation/innovation of wind farm life cycle

➢ Innovative substructure concepts

# Overview

- Introduction
- Foundation Optimisation
  - XL Monopiles
  - Gravity Base Foundations
- Concept Development
  - Floating Jackets
  - Floating Platform

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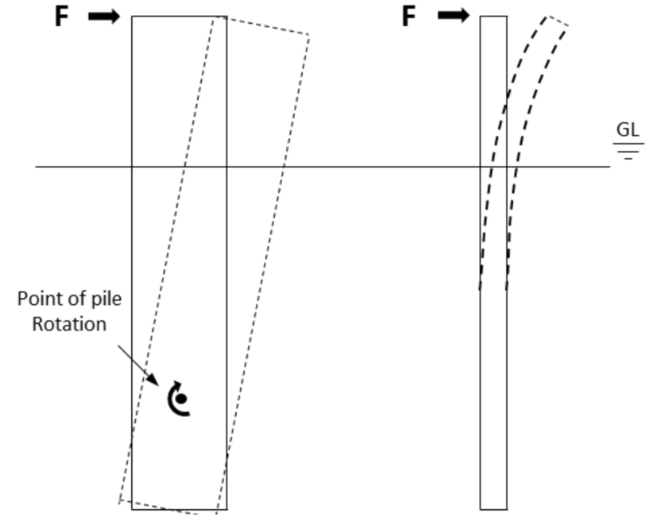
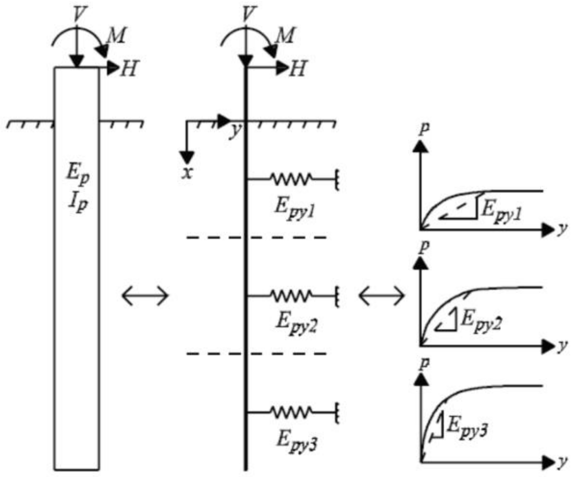
# Monopile Design



## Traditional Monopile Design

- Lateral Pile Response typically using 1D FE 'p-y' approach
- API 'p-y' curves derived from small diameter (0.6m diameter), slender pile tests – Not suitable for monopiles typically >4m
- API approach thought to be conservative for monopiles
- Implemented in 1D FE model software (Lpile)

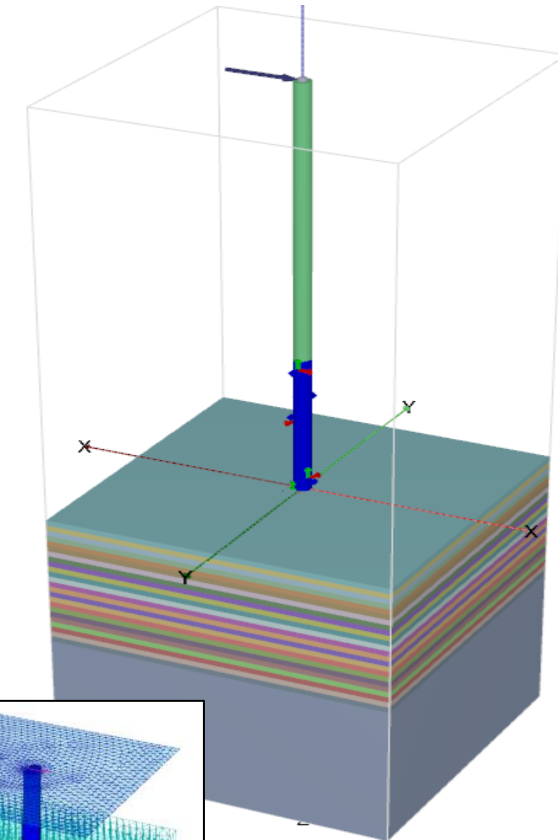


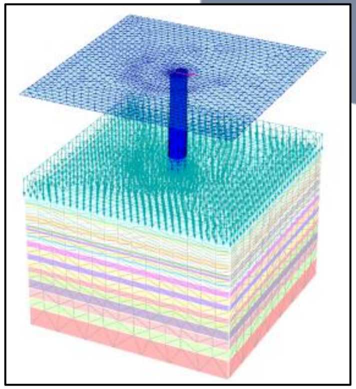



# XL Monopile Study

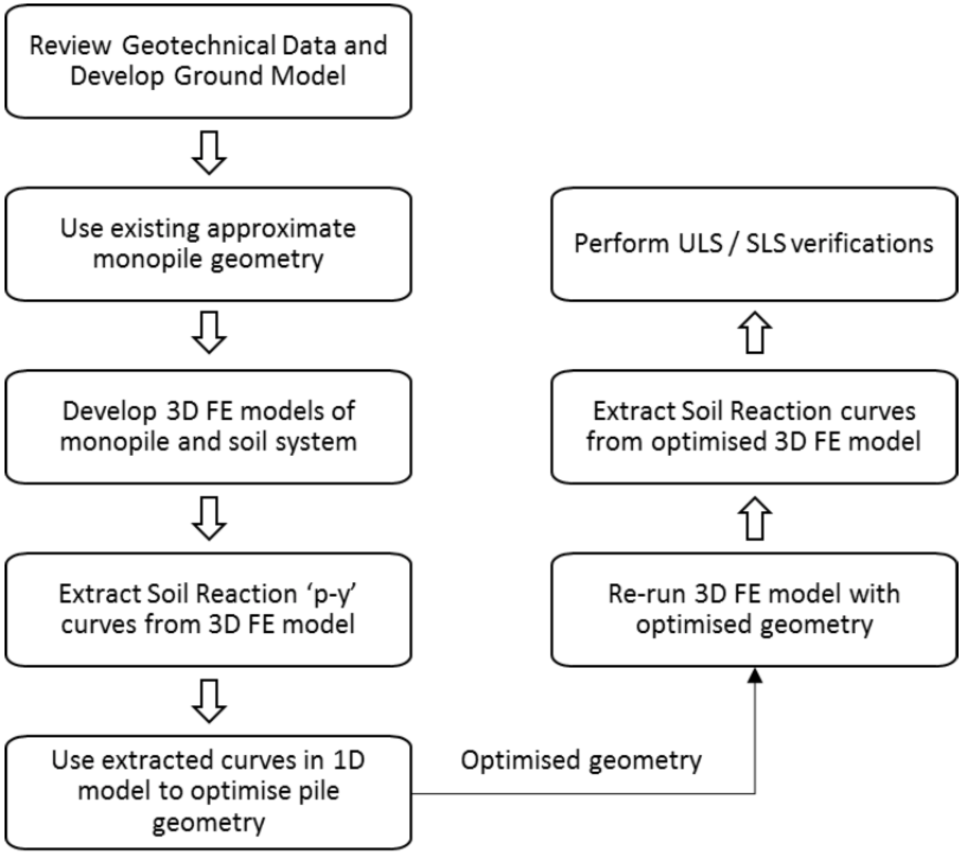
**Comparison of XL Monopile design according to API versus novel FEM-based methods**

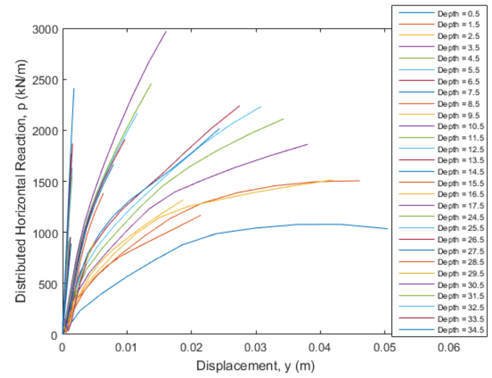
- Numerical modelling of XL monopiles with various diameters under the static loads
- D= 6.5m, 8.0m, 9.5m      L/D=5.0m
- Generic North Sea soil profile
- Modelling monopile geometry and associated loads in Lpile to obtain API results

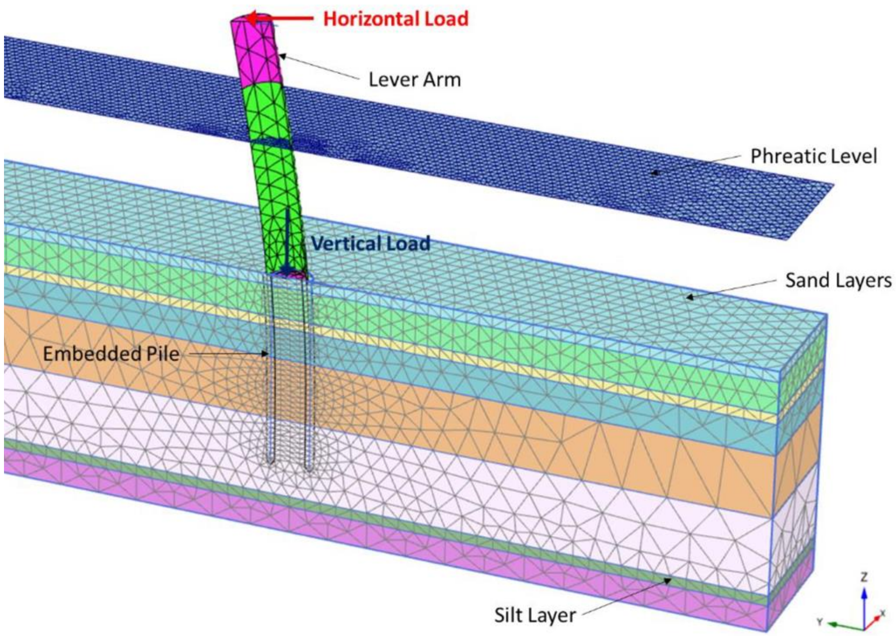




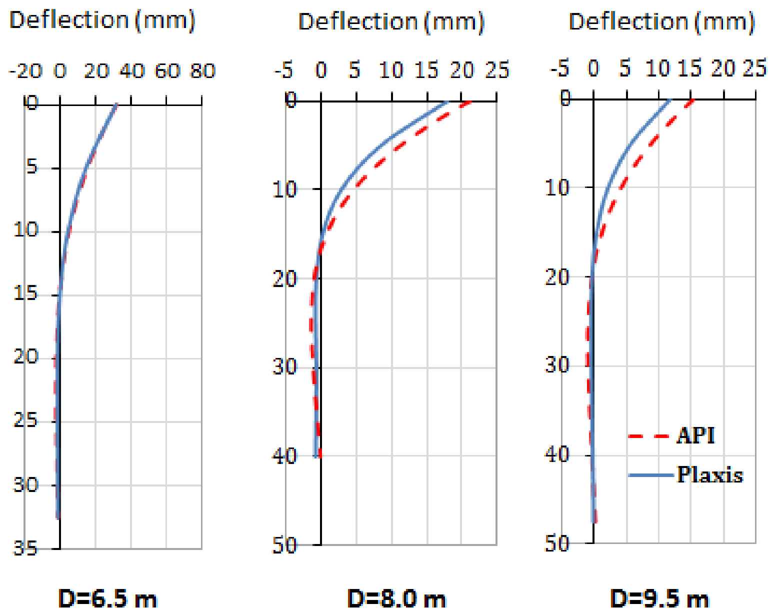
# 3D FE Design Approach



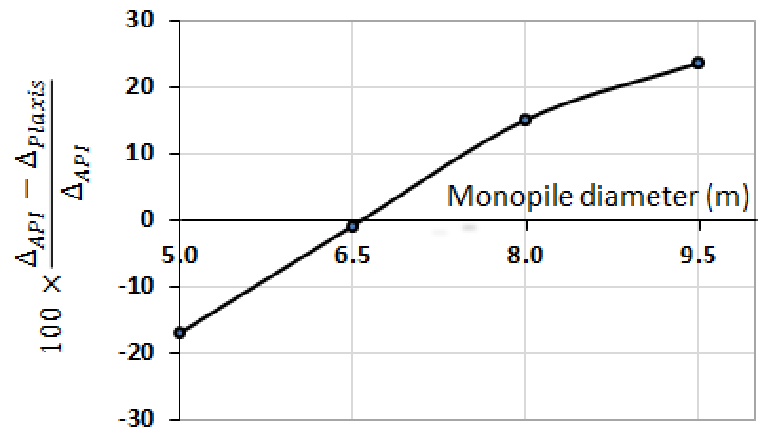



# Comparative Study




**evaluation of modelling assumption on the lateral capacity & possible cost savings**




**The reliability of the API approach depends not only on the monopile diameter, but also on the range of stresses the soil undergoes.**

**Publication** ➡

Attari et al., (2015) Comparative Study of the Design Methods for Large Diameter Offshore Monopiles. The European Wind Energy Association Annual Event 2015

# Monopile Design



## Monopile Design – FLS & DLS case

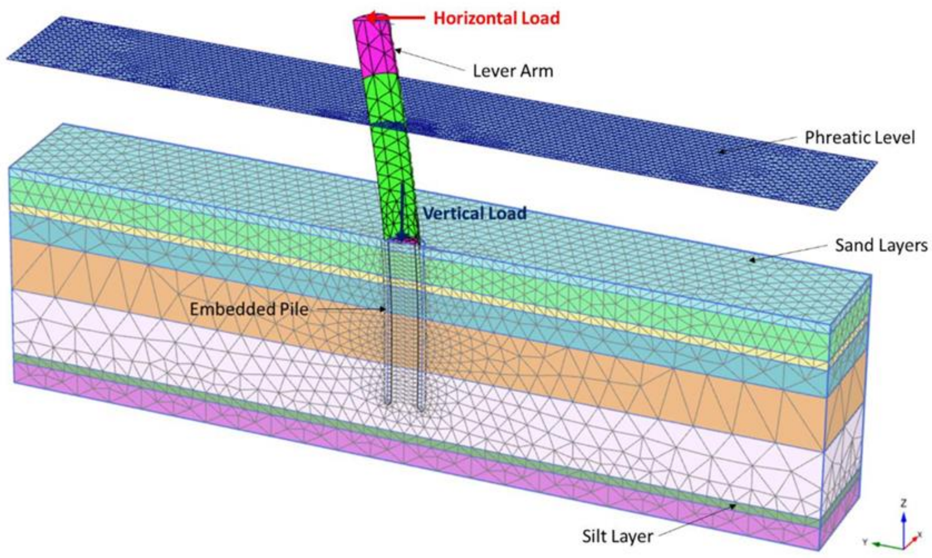
- Structural fatigue checks - Materials within structure to last beyond specified design life.
  - Fatigue check performed using linearized 'p-y' springs
  - Should use secant 'p-y' stiffness under normal operating loads (Design Equivalent Loads)
  - Need to work very closely with turbine suppliers

- Dynamic checks to ensure natural frequency of structure lies outside exclusion bands, ….

- Stiffness and Damping are key to dynamics and fatigue

# Industry Impact

- More efficient design approaches result in
  - Reduction in monopile size
  - Reduction of steel tonnage below mudline
  - Saving money on cost of steel, cost of transport, cost of installation (offshore time)….
  - Significant CAPEX cost reductions



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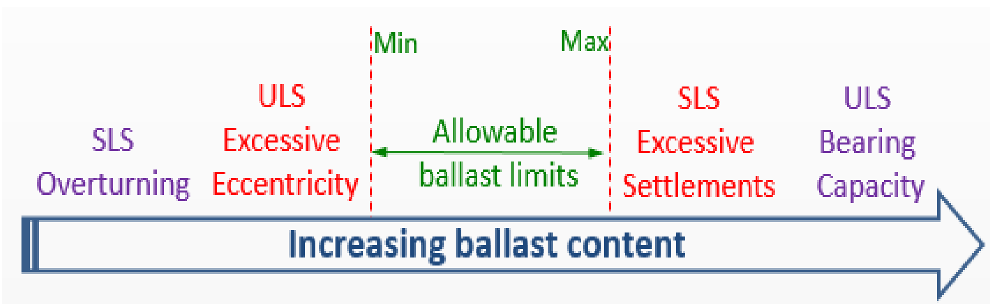
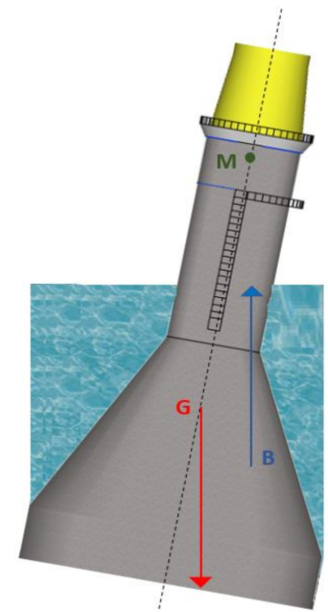
# GBF Design

There are two sides to the design of a GBF:

- Maintaining sufficient stability
- Weight optimisation




- Cost Drivers
  - Material & Construction Costs
  - Cost of Marine Operations
  - Port & Infrastructure Costs



## Parametric Study of a Self-Buoyant GBF

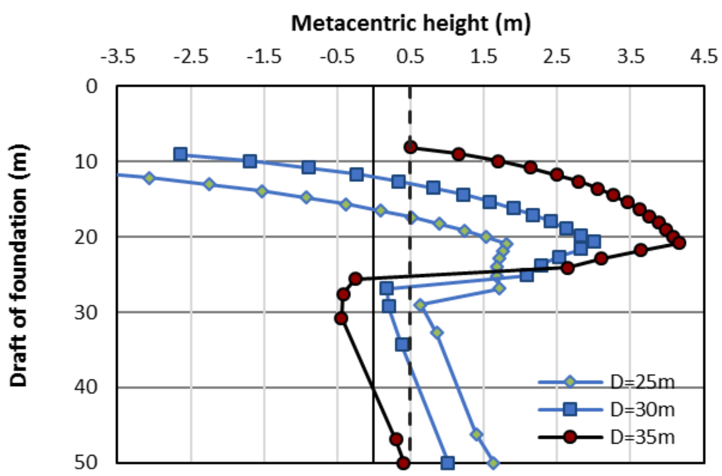
**Objective**: Making the structure lighter while maintaining stability

Some of the variables considered included:

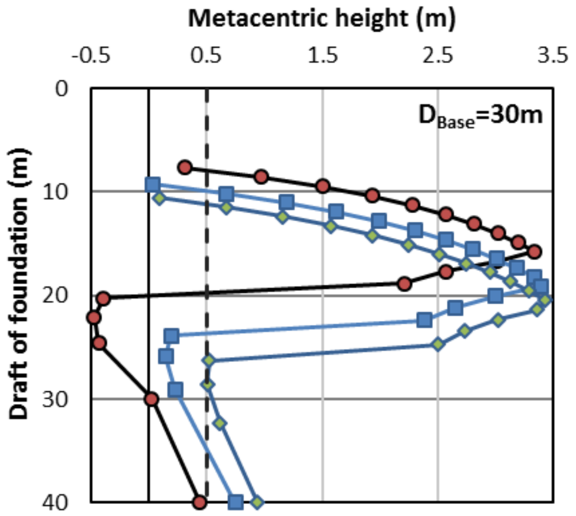
- Base diameter
- Height of compartments
- Height of the conical part of foundation
- Ballast mass

**Publication**

Attari et al., (2016) "Design Drivers for Buoyant Gravity-based Foundations". Journal of Wind Energy.




Variation of metacentric height with base diameter during ballasting (WD=50m; $H_{cylinder}$=20m; $H_{Cone}$=15m)

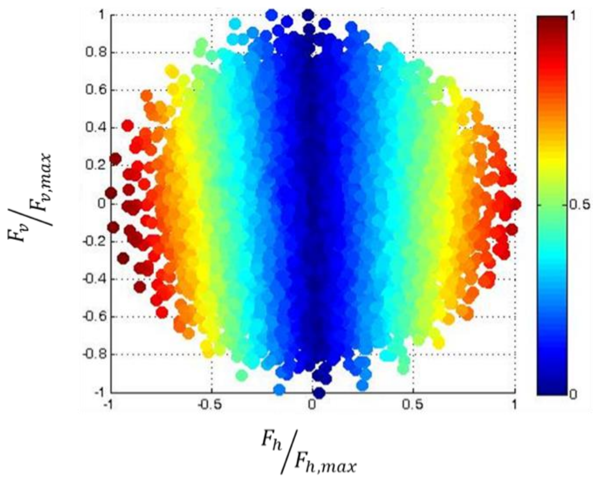


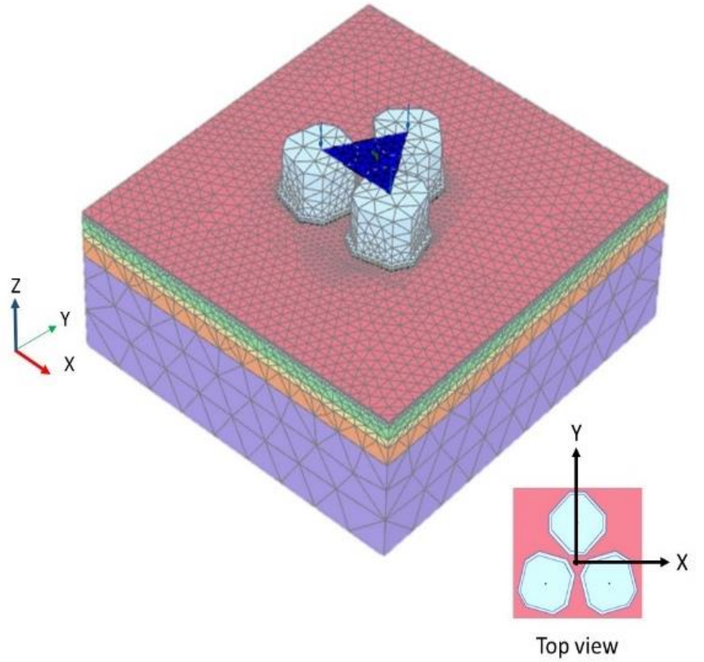

Variation of metacentric height during ballasting at DBase=30m (WD=40m; HCone=15m)

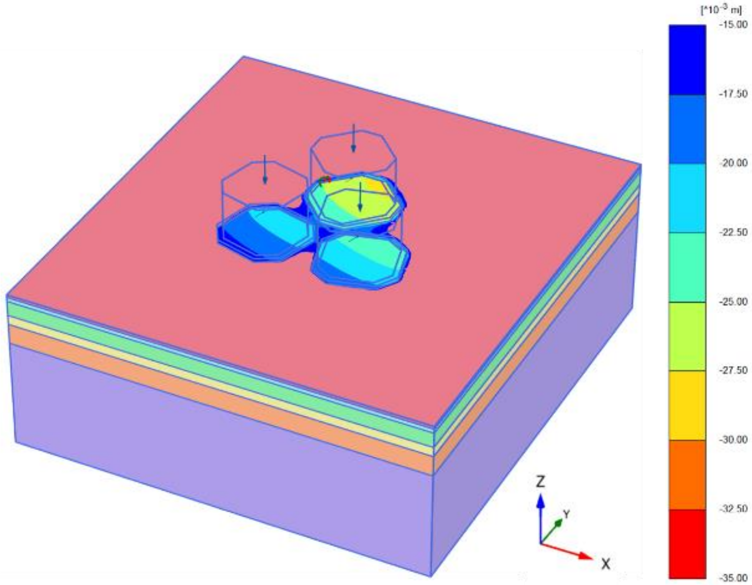
# GBF- Geotechnical Design



- Geotechnical Design of GBFs
- Detailed analysis of cyclic pore pressure response
- Advanced 3D FE analysis and analytical checks

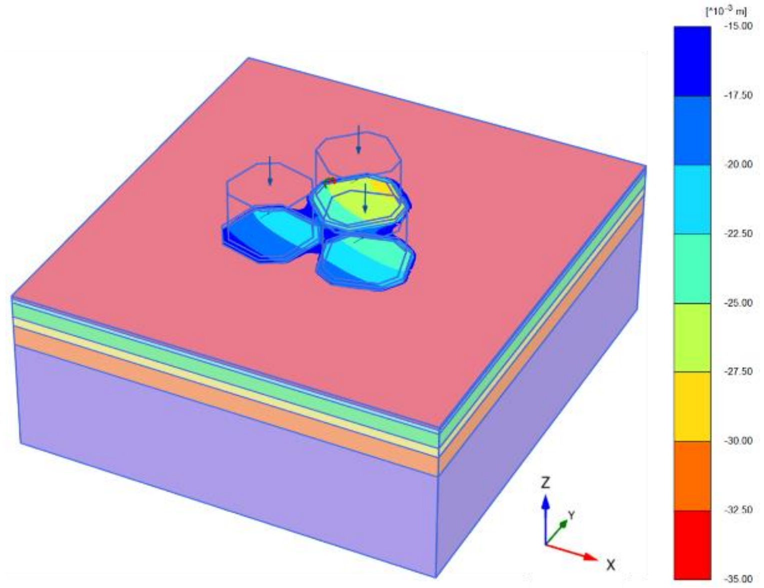


## Gravity Base Design

- Bearing Capacity
- Settlement / Differential
- Sliding
  - Change in design guidance DNV (2014)
  - Pre 2014 – $H_d < V_d \, . \, \tan(\varphi) < 0.4$
  - Post 2014 - $H_d < r. \; V_d \, . \, \tan(\varphi)$
  - r is roughness parameter which is 1.0 for soil – soil or <1 for soil structure



GEOTECHNICAL DESIGN DRIVER – SLIDING !

# Industry Impact

- Researching on geometrical optimisation of these structures has contributed to:
    - Lowering material consumption by designing lighter yet equally stable foundations
    - Savings in manufacturing costs
    - Elimination of expensive jack-up vessels by towing and ballasting gravity based foundations
    - Significant savings in transportation and installation costs

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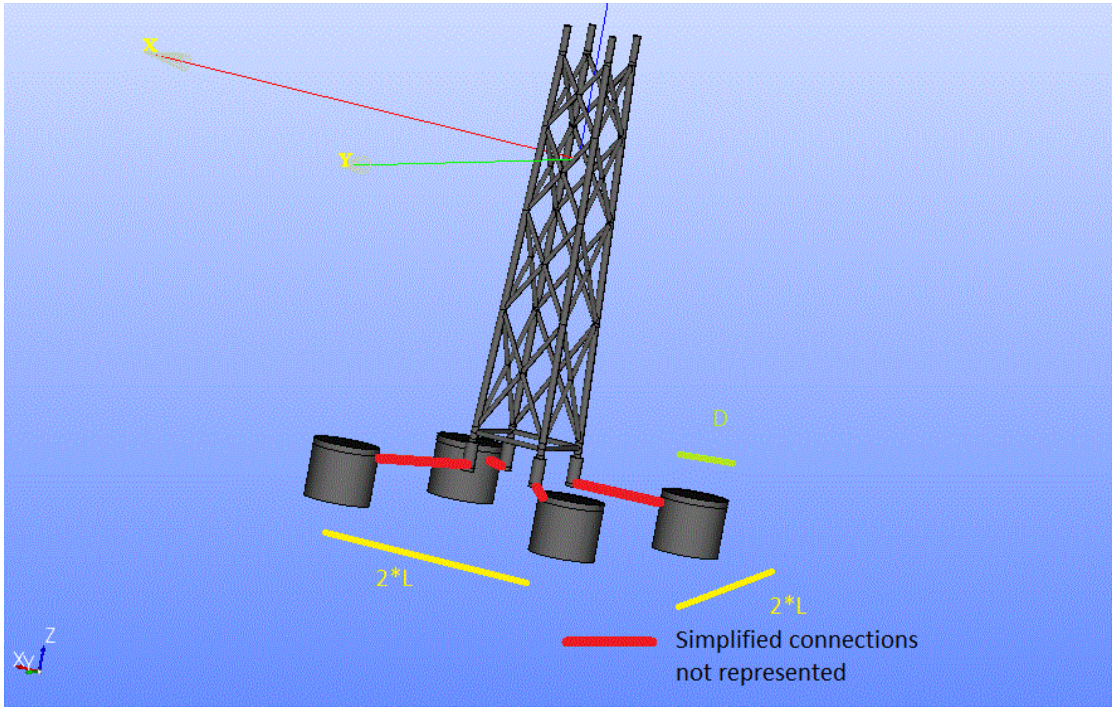
# Floating Jacket Design



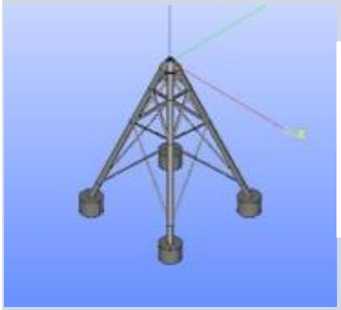
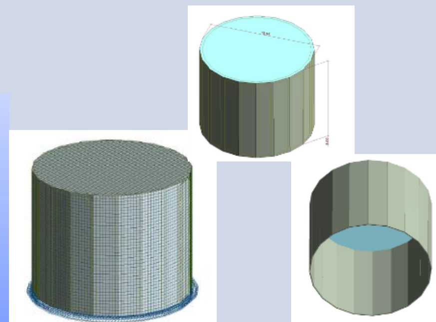
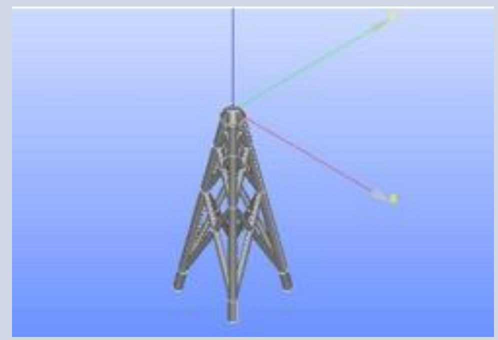
## Floating Jacket Design with the Use of Suction Buckets

- Design of a floating jacket
- Design of suction caissons as buoyancy tanks
- Structural rationalisation of the caissons (Geotechnical/structural capacity check of suction buckets)



# Floating Jacket Design

Two sets of design optimisations were done for jacket foundations:

| Optimised designs for jackets brought on site floating | Optimised designs for jackets brought on site non-floating |
|---|---|
|   ROBOT STRUCTURAL ANALYSIS PROFESSIONAL |  |

| | Jacket brought floating on site | Jacket brought on barge |
|---|---|---|
| Jacket Stucture Weight | 1200 – 1450 Tonnes | 1200 – 1800 Tonnes |
| Foundation Weight | Suction buckets: 420 Tonnes | Not evaluated in the framework of the study |
| Ballast Weight | 300 Tonnes | 0 |
| Transportation mean | Tug | Barge & Tug |
| Installation mean | Vessel, possibly with reduced lifting capacity | Vessel with conventional lifting capacity |

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# Conclusion

## Conclusions

- Offshore Wind Industry undergoing significant expansion over the coming decade
- Costs are rapidly falling as the industry matures and converges on optimum technical solutions and specific design procedures
- The Leanwind design procedures are being applied in industry today.

# Thanks for your attention!


Photo credit: Deme Group.