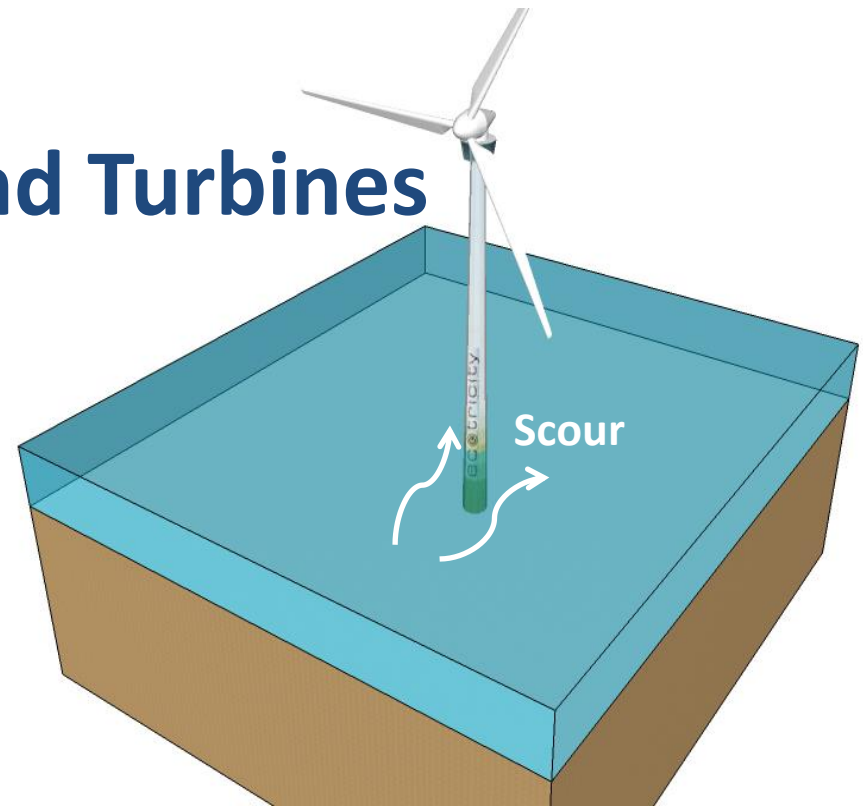


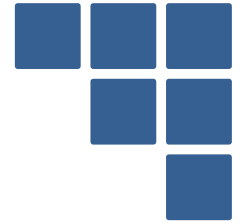
Lecture

# Scour on Offshore Wind Turbines

**Luke J. Prendergast PhD**

*15<sup>th</sup> November 2016*

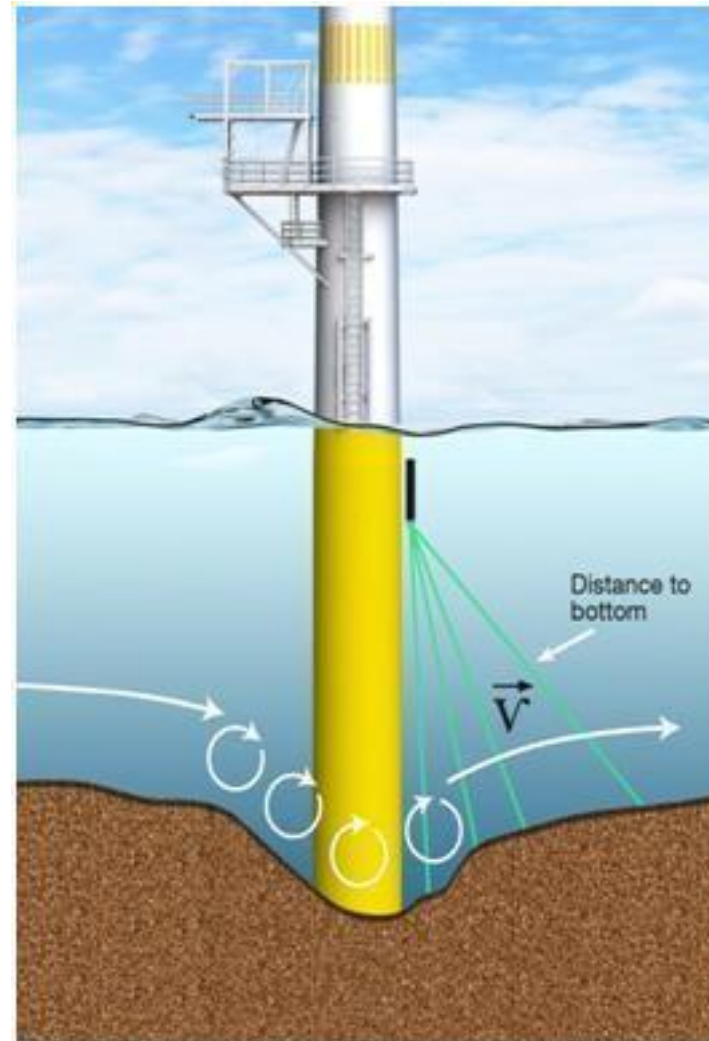
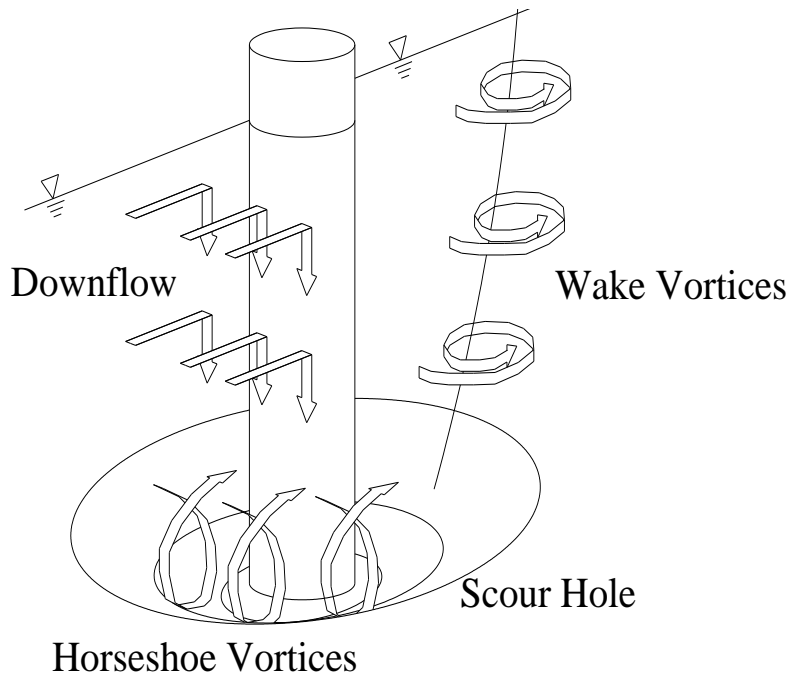
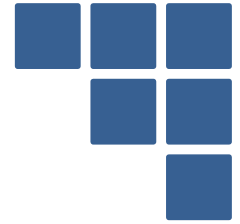




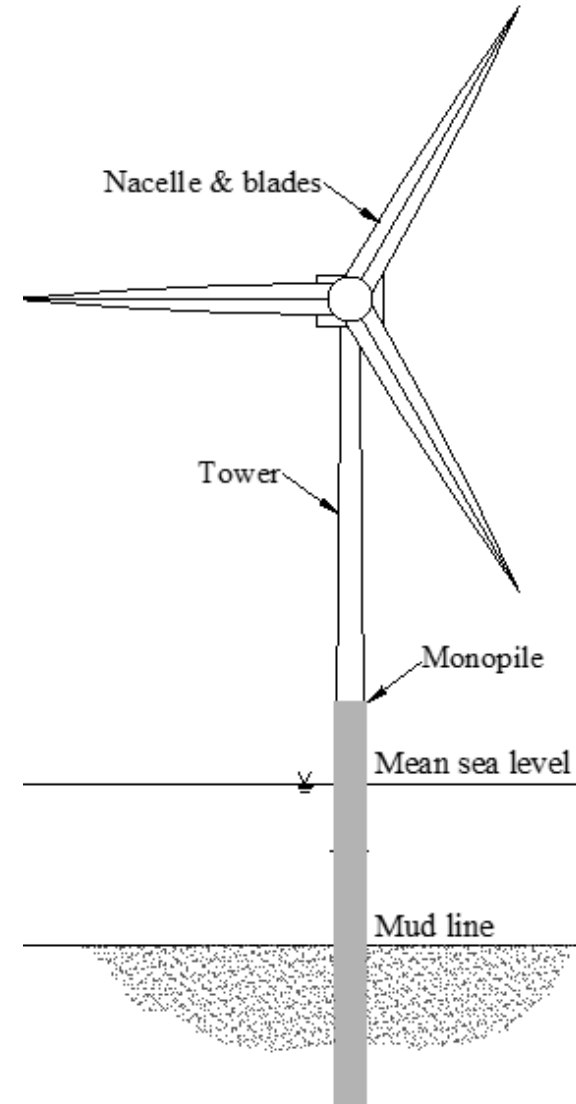
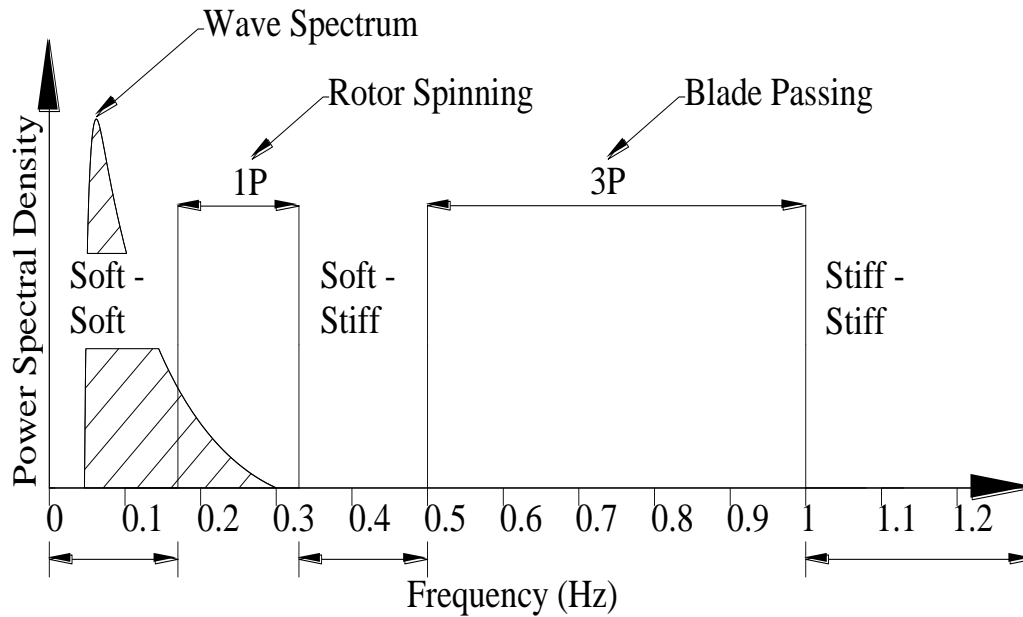
# Scour Erosion - Introduction

1. Introduction to Scour
2. Research Approach
3. Experimental Analysis
4. Numerical Modelling
5. Full-Scale Turbine Modelling
6. Summary

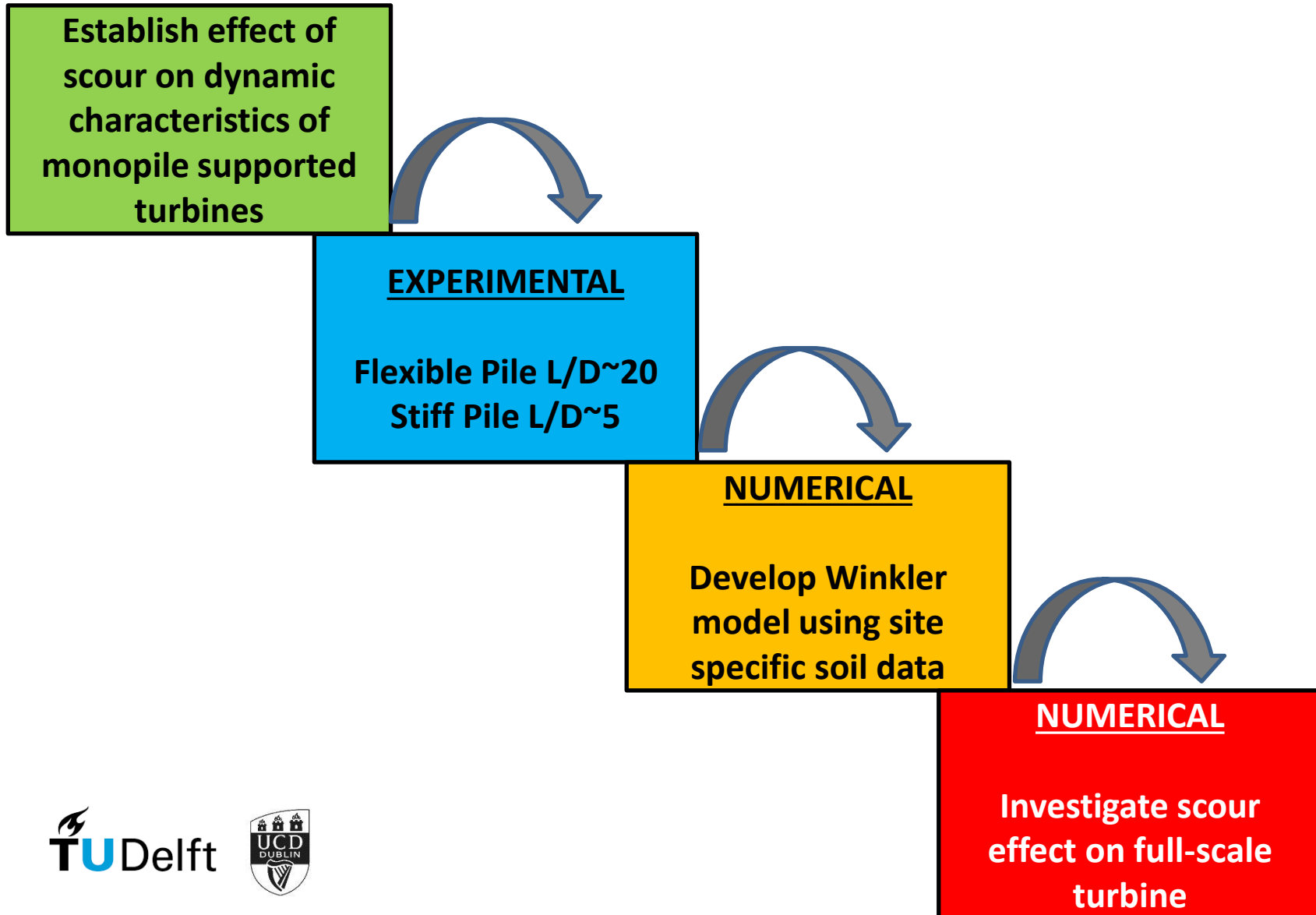
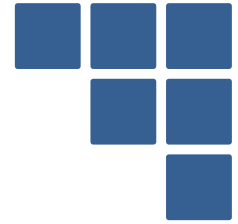
# Scour Erosion - Introduction



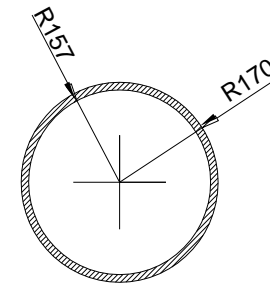
# Wind Turbines – Dynamically Sensitive



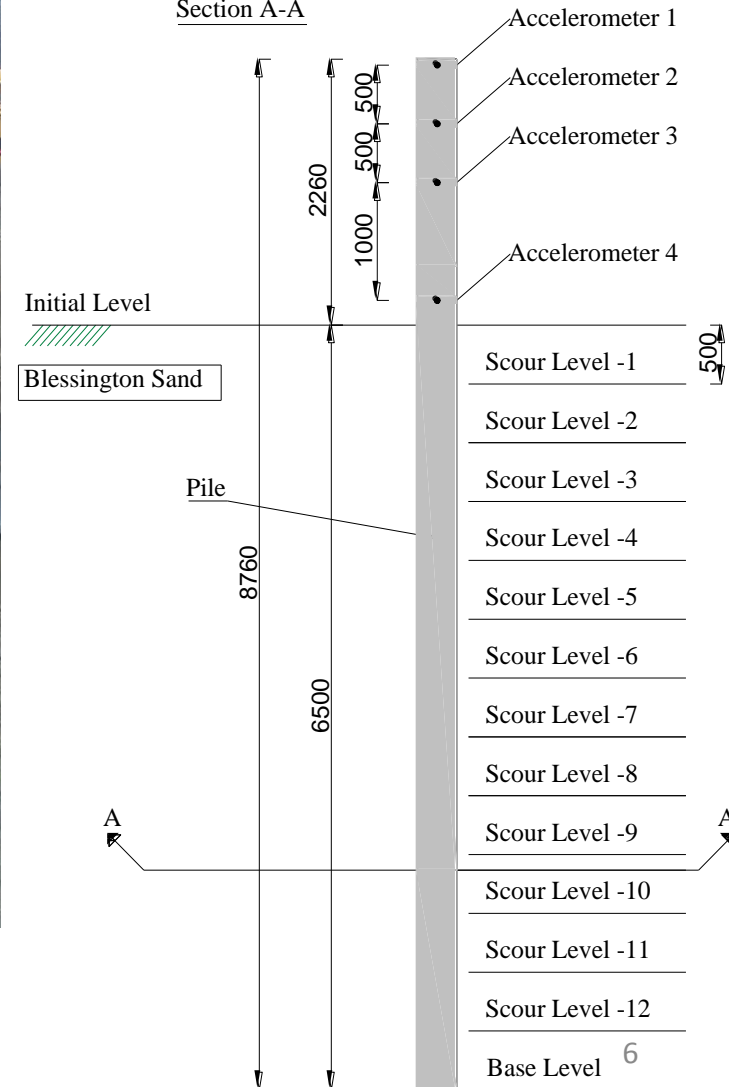
# Scour Erosion – Research Method



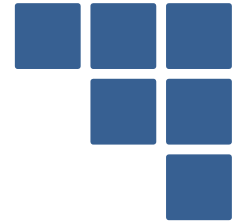
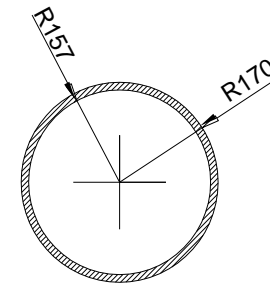
# Scour Erosion - Experimental



Section A-A

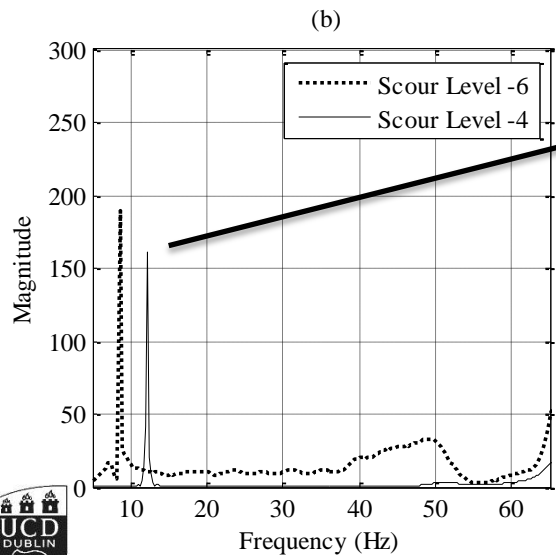
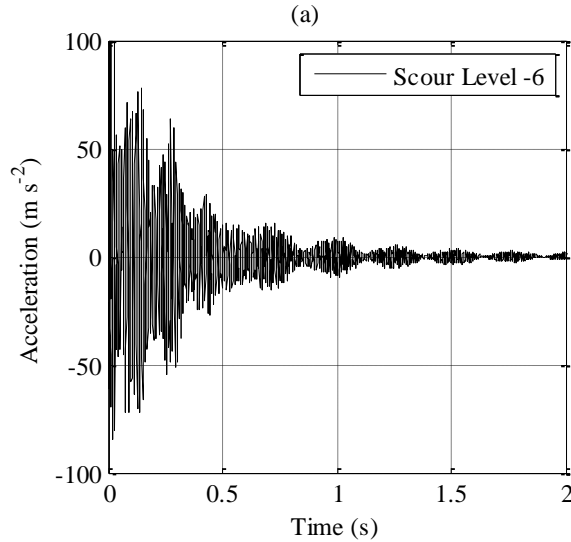


# Scour Erosion - Experimental



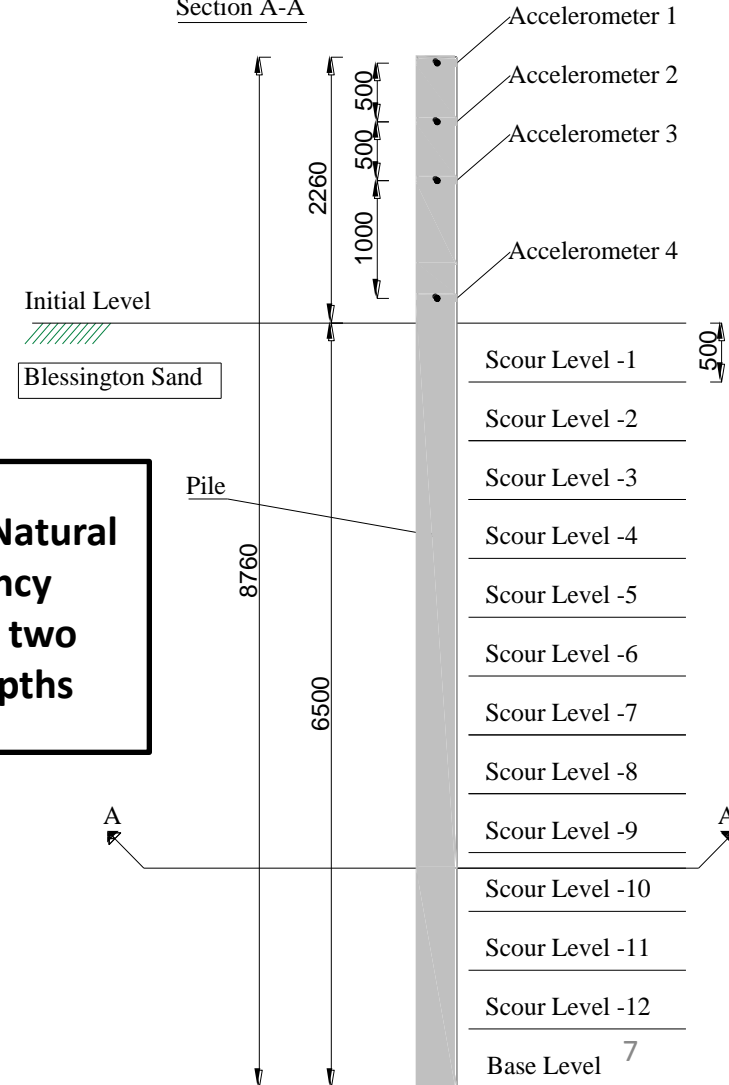
Impact with hammer

Calculate Frequency using Fourier Analysis

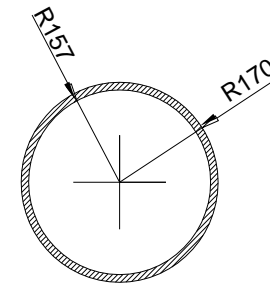
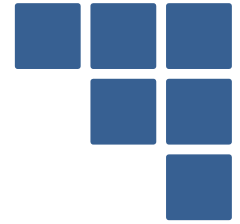


Change in Natural Frequency between two scour depths

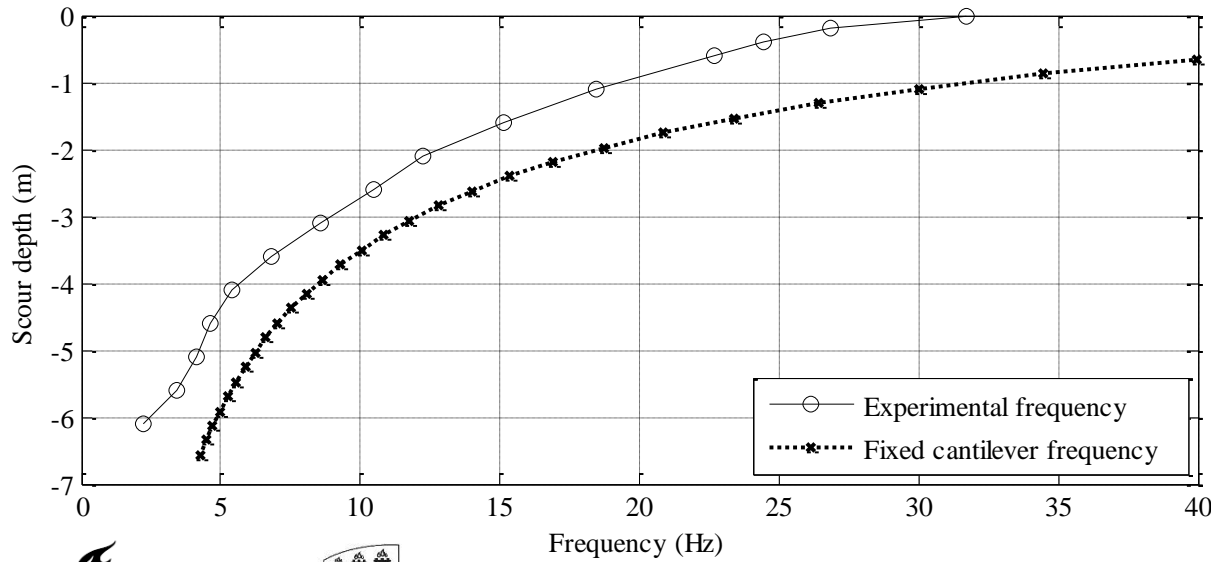
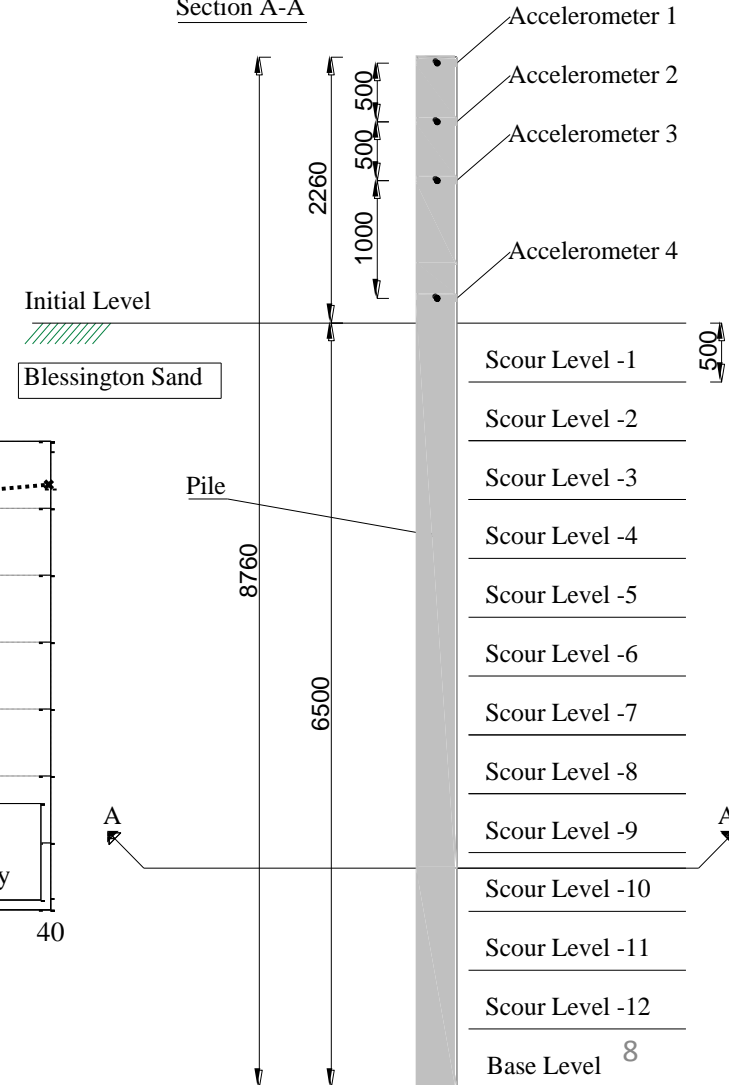
Section A-A



# Scour Erosion - Experimental

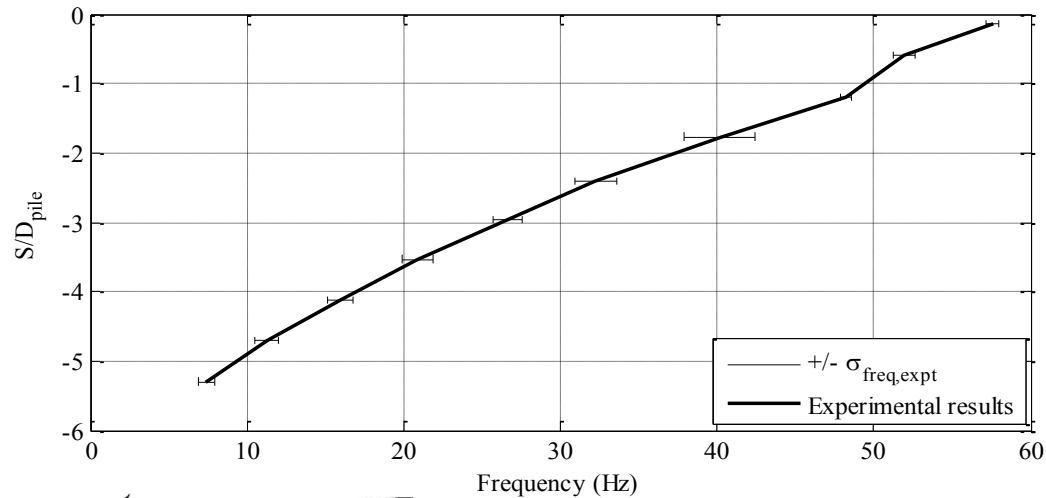
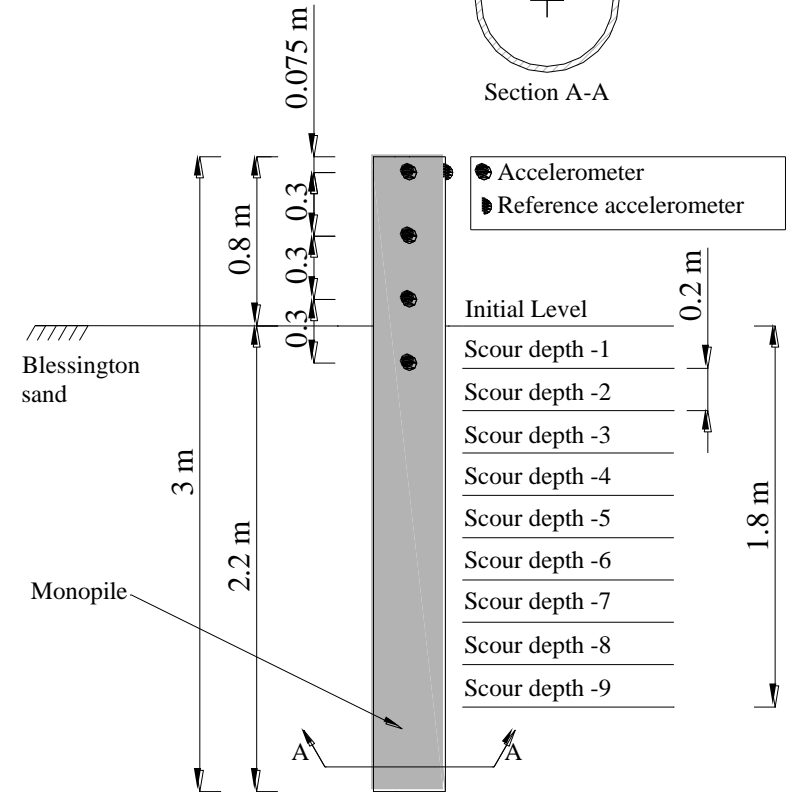
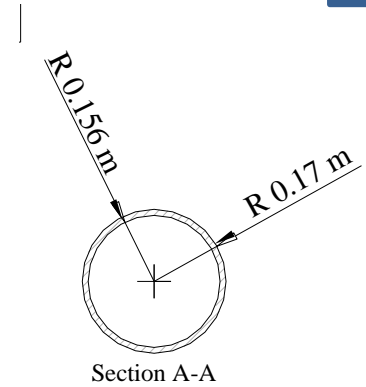
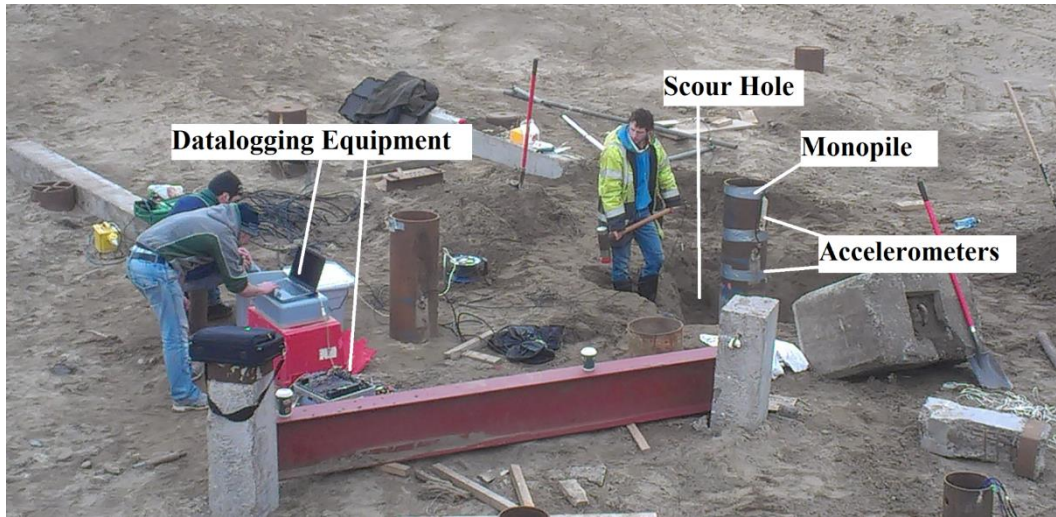


Section A-A





# Scour Erosion - Experimental





# Scour Erosion – Numerical Model

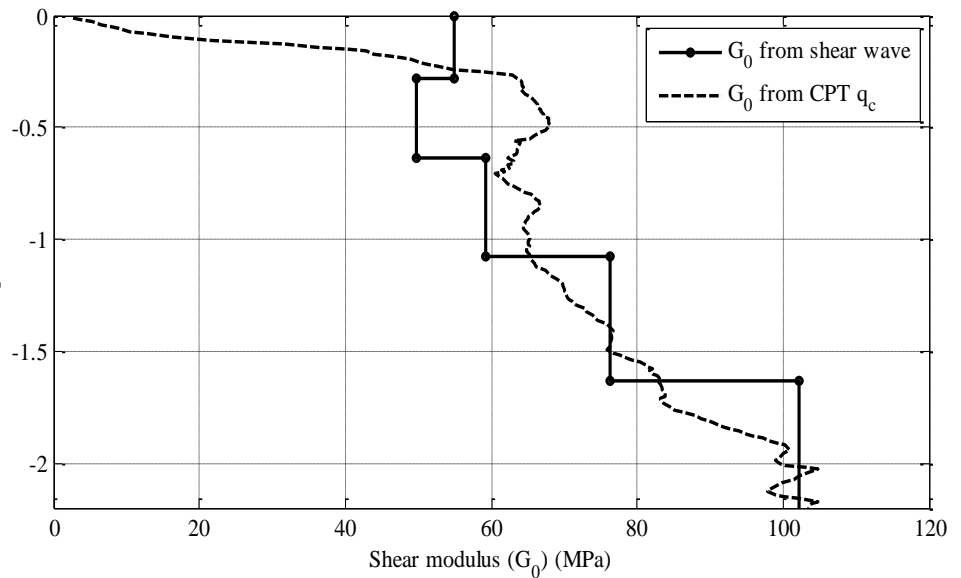
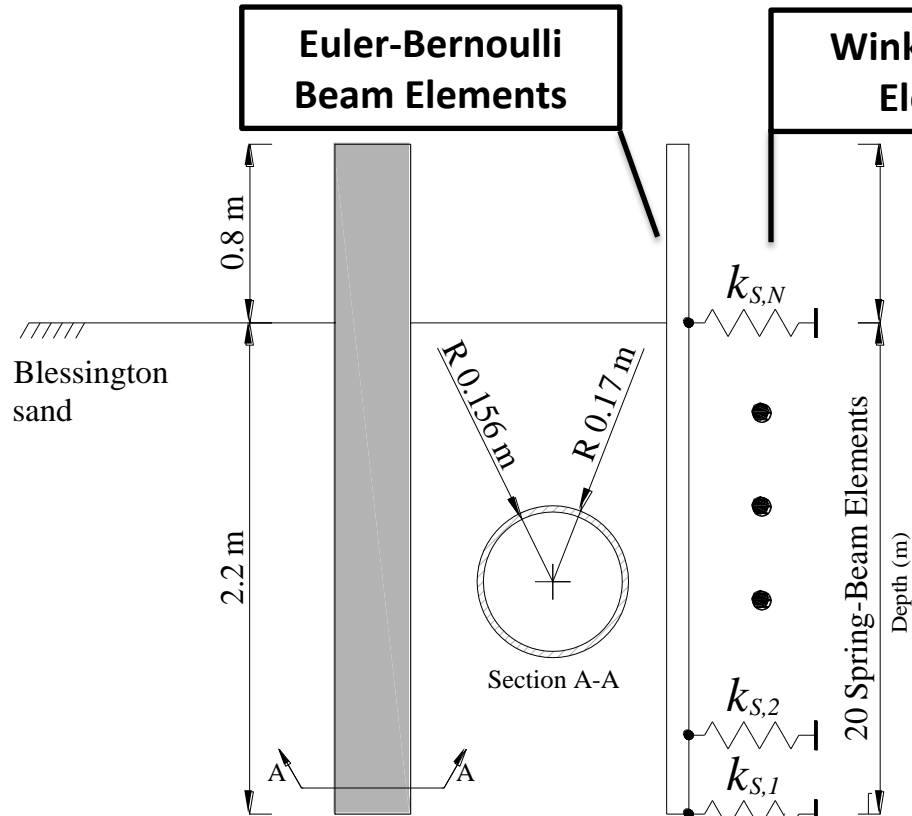
$$[M_G] \begin{Bmatrix} \ddot{x}_1(t) \\ \ddot{x}_2(t) \\ \vdots \\ \ddot{x}_N(t) \end{Bmatrix} + [C_G] \begin{Bmatrix} \dot{x}_1(t) \\ \dot{x}_2(t) \\ \vdots \\ \dot{x}_N(t) \end{Bmatrix} + [K_G] \begin{Bmatrix} x_1(t) \\ x_2(t) \\ \vdots \\ x_N(t) \end{Bmatrix} = \begin{Bmatrix} F_1(t) \\ F_2(t) \\ \vdots \\ F_N(t) \end{Bmatrix}$$

$$[K_{s,i}] = k_{s,i} \begin{bmatrix} 1 & -1 \\ -1 & 1 \end{bmatrix}, \quad k_{s,i} \geq 0$$

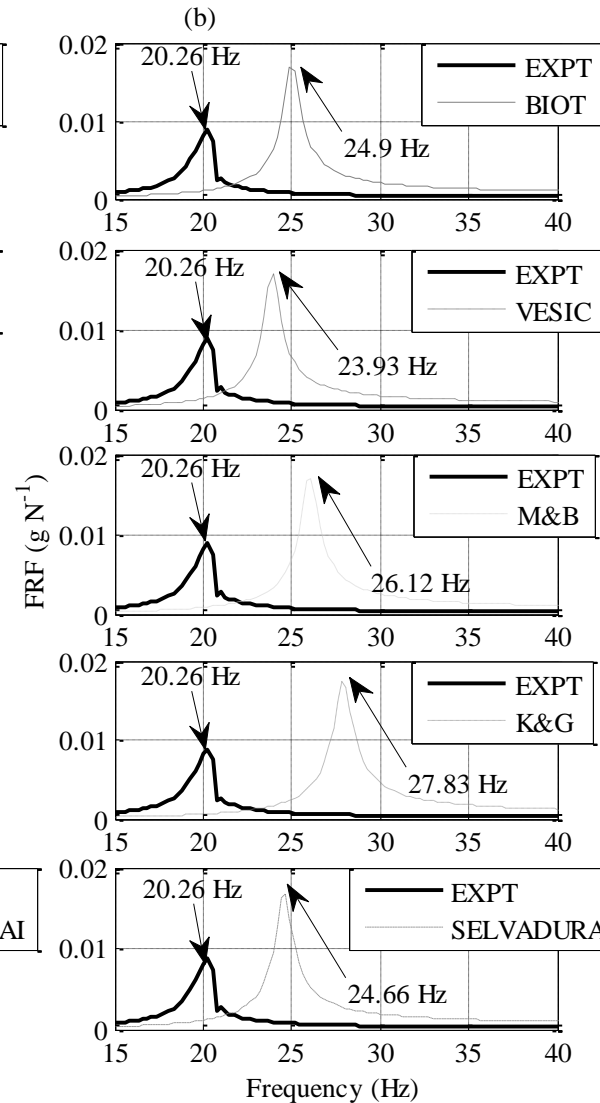
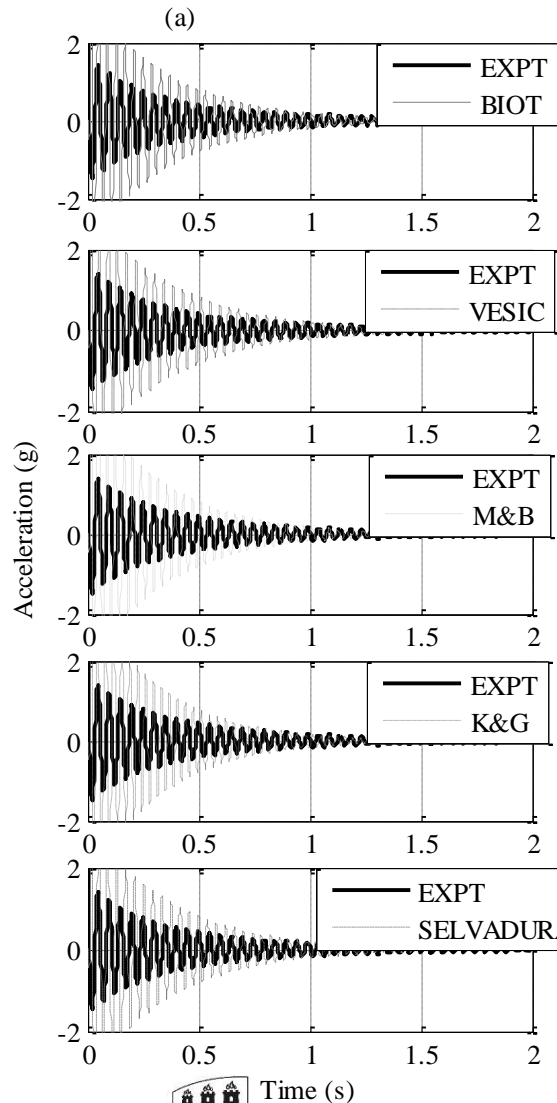
**Euler-Bernoulli  
Beam Elements**

**Winkler Spring  
Elements**

**Small-strain soil stiffness from site used  
to derive soil spring stiffness**



# Scour Erosion – Numerical Model



## Subgrade Reaction Models

$$k_s = \frac{0.95E_0}{D(1-\nu_s^2)} \left[ \frac{E_0 D^4}{(1-\nu_s^2)EI} \right]^{0.108} \quad [1]$$

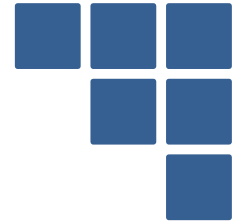
$$k_s = \frac{0.65E_0}{D(1-\nu_s^2)} \left[ \frac{E_0 D^4}{EI} \right]^{1/12} \quad [2]$$

$$k_s = \frac{E_0}{D(1-\nu_s^2)} \quad [3]$$

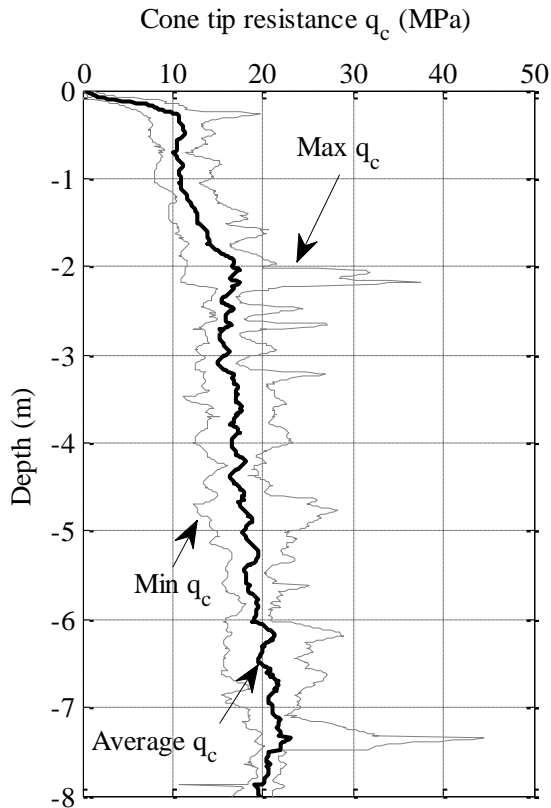
$$k_s = \frac{2E_0}{D(1+\nu_s)} \quad [4]$$

$$k_s = \frac{0.65}{D} \frac{E_0}{(1-\nu_s^2)} \quad [5]$$

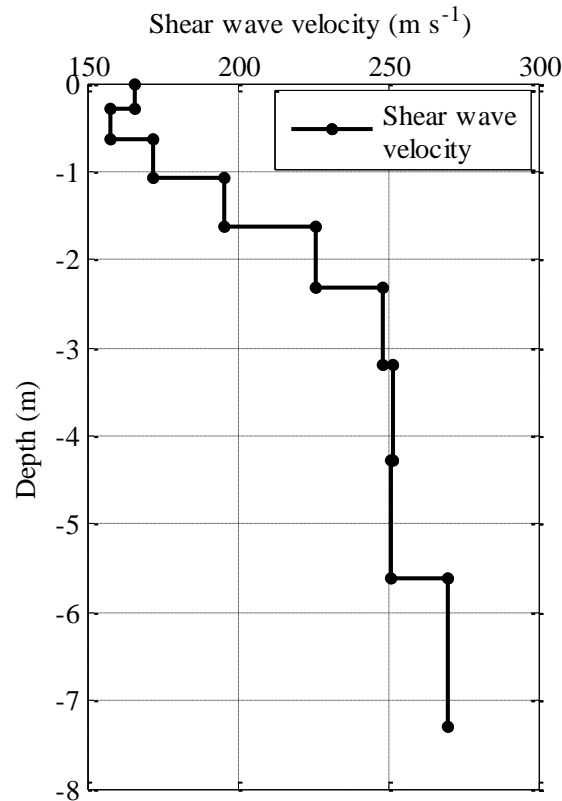
# Scour Erosion – Numerical Model



**Two methods used to derive site-specific soil data**



(a)



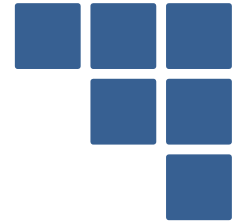
(b)

**[1] Correlation to Cone Penetration Test data**

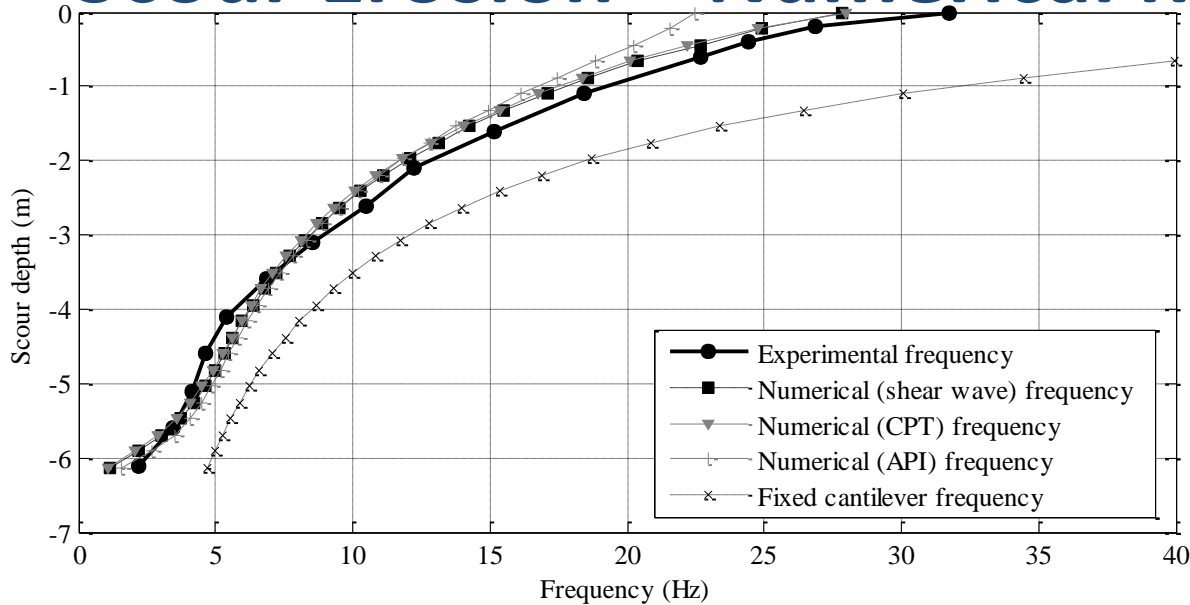
$$G_0 = 6q_c$$

**[2] Correlation to Shear Wave Velocity data**

$$G_0 = \rho v_s^2$$

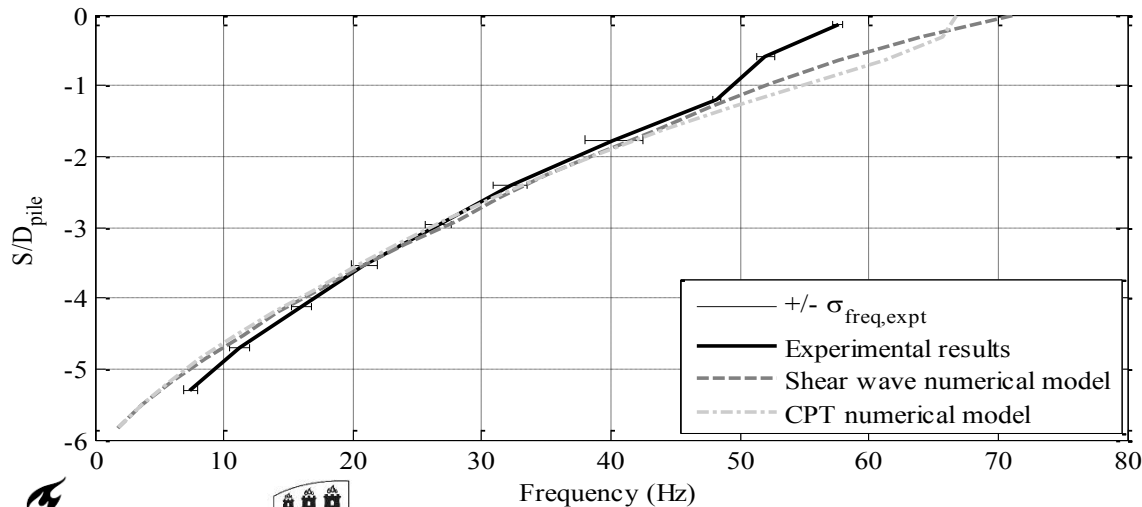


# Scour Erosion – Numerical Model



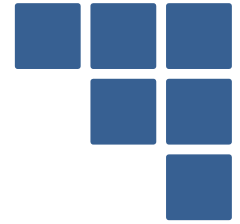
**Pile with L/D ~ 20**

$$k_s = \frac{E_0}{D(1-\nu_s^2)} \left[ \frac{E_0 D^4}{EI} \right]^{1/12}$$



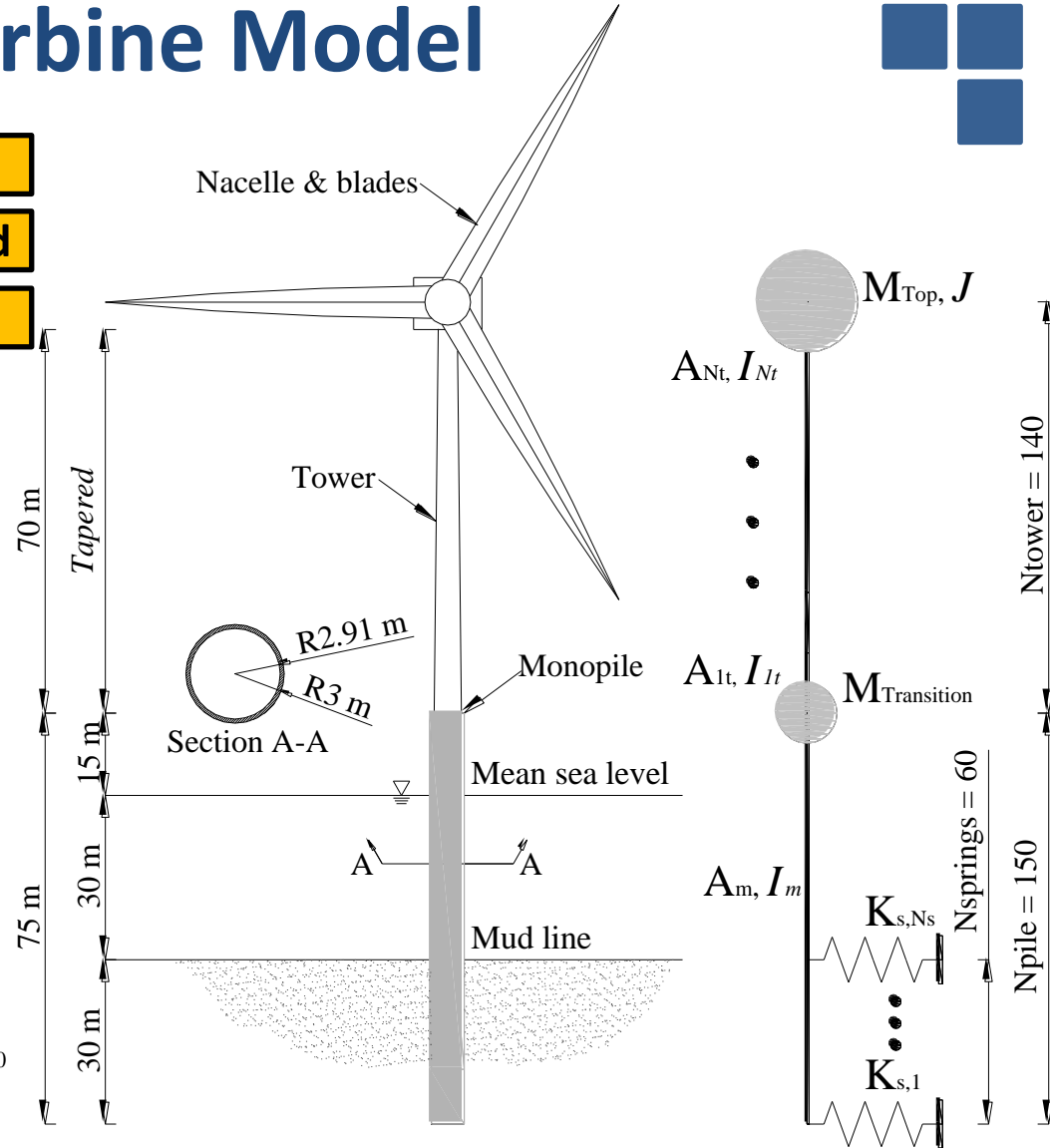
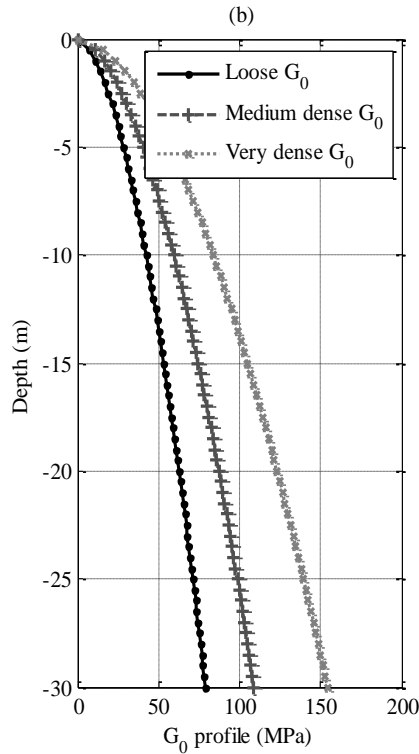
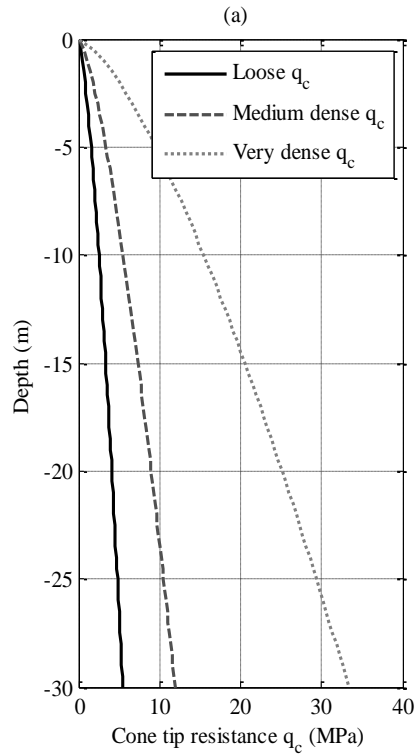
**Pile with L/D ~ 5**

# Scour Erosion – Turbine Model

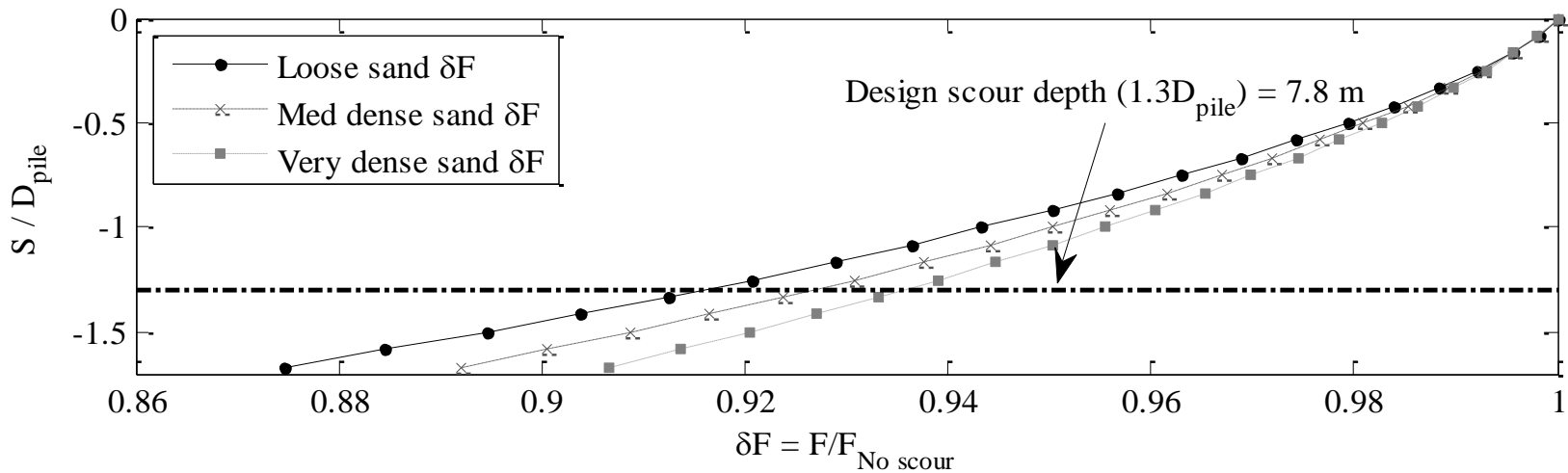
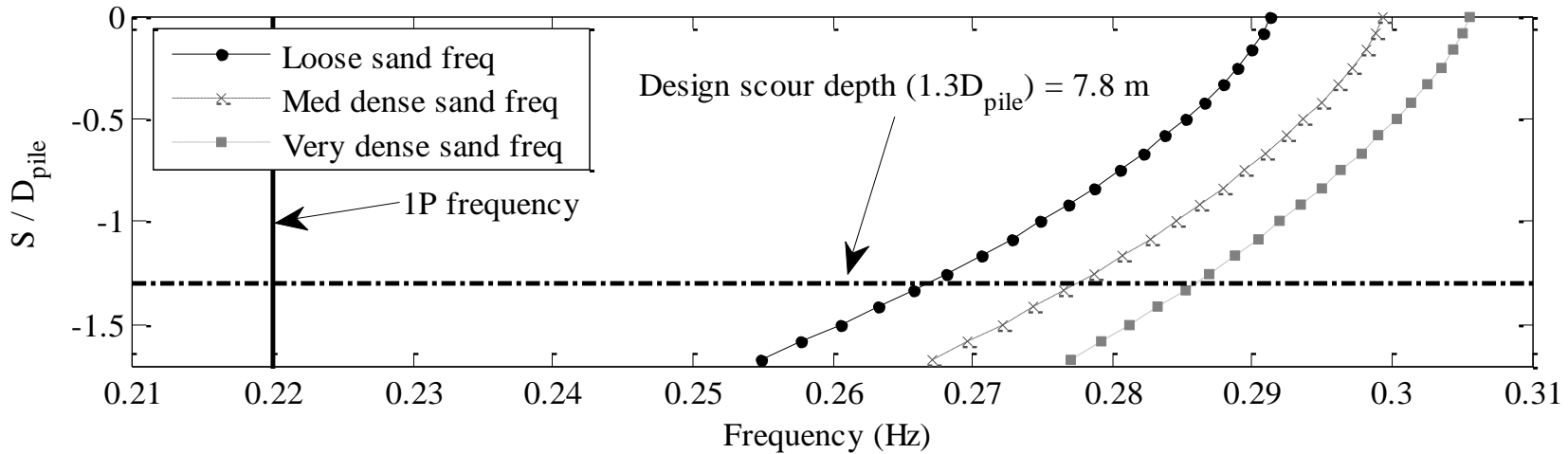


**Representative  $q_c$  profiles created**

**Loose sand**  
**Med dense sand**  
**Dense sand**



# Scour Erosion – Turbine Model



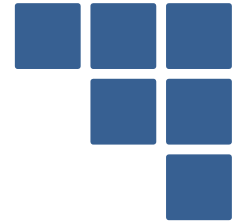
# Summary



- Scour has a significant effect on the natural frequency of a pilot-scaled monopile
- Offshore wind turbines are dynamically sensitive therefore scour may represent a significant risk to stability
- Scour can be combatted at design stage by allowing for an increased effective monopile length however the accurate specification of operational soil stiffness is imperative to the safe operation
- There is still uncertainty surrounding cyclic loading effects on operational stiffness
- As well as dynamic stability, scour has a significant effect on lateral ultimate capacity, not covered in this discussion



# Thank you for your attention!



## Acknowledgements

- Prof. Kenneth Gavin, Subsurface Engineering, TU Delft
- The Geotechnical Research Group at University College Dublin



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EUROPEAN REGIONAL  
DEVELOPMENT FUND



An Roinn Post, Fiontar agus Nuálaíochta  
Department of Jobs, Enterprise and Innovation

## HEA

Higher Education Authority  
An tÚdarás um Ard-Oideachas

