Modelling installation of screw piles using the Material Point Method

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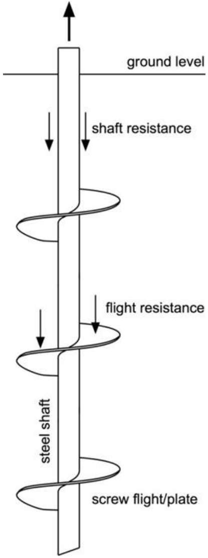
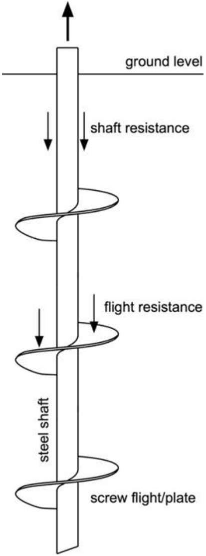
Screw piles for wind energy foundation systems

- Screw (or helical) piles are foundations which are screwed into the ground.
- This project aims to make screw piles a more attractive foundation (or anchoring) option for offshore wind farms.
- This project will develop piles with optimised geometries that minimise resistance to installation but are capable of carrying high lateral and moment loads.



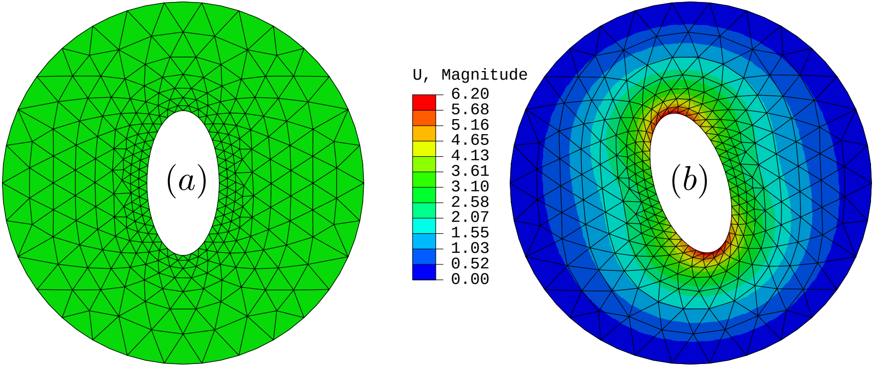
Numerical modelling of pile installation

- Assessment of the load-bearing capacity of an in-site pile requires the knowledge of the surrounding soil state.
- The soil is significantly distorted by the installation of the pile, so it is essential to account for this history. However, many published papers ignore this.



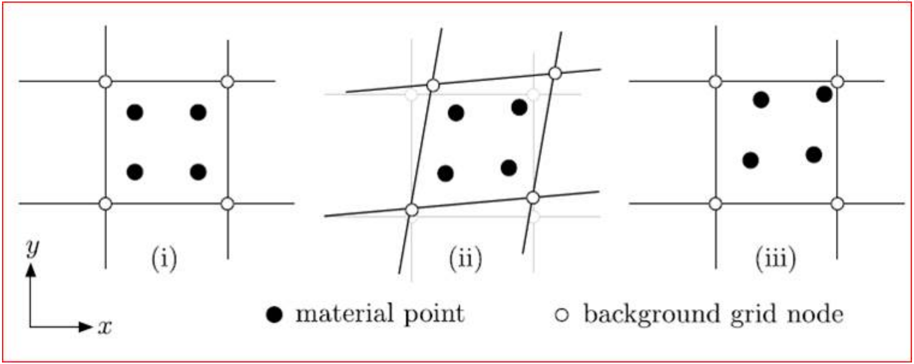
FEA and distortion of element

Finite Element Analysis (FEA) is UNABLE to handle large deformations without the computationally expensive task of re-meshing and mapping of history variables.



The FEA aborted after a twist about 10° *on the ellipse.*

The Material Point Method (MPM)



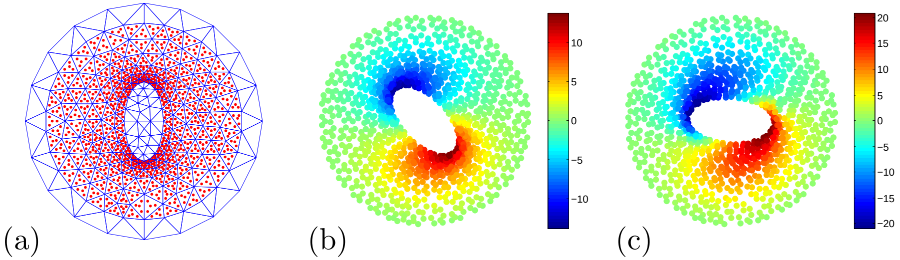
(i) Information held at material points is mapped to grid nodes,

(ii) Solve equilibrium equations on grid nodes for deformation subject to loading increment,

(iii) Material points hold the deformation.

Repeat above steps with quality undistorted grid for a new loading increment.

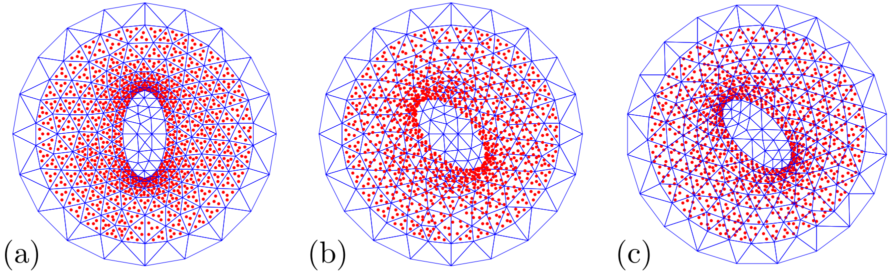
The MPM is successful for any large deformation.



(a) computational mesh and material points. Horizontal displacement subject to a twist of 45° (b) and 90° (c).

Moving mesh

Moving mesh: a mesh always conforming with the boundary of the deformed body.

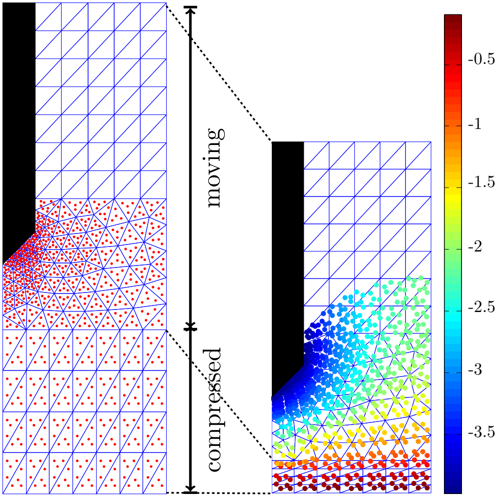


(a) initial computational mesh and material points, material points after rotation 45° with initial mesh in (b) and with a moving mesh in (c).

Moving mesh is used for rotation.

Moving mesh

- Moving mesh is used for translation.
- In 3D modelling of screw pile installation, both rotation and translation are involved.



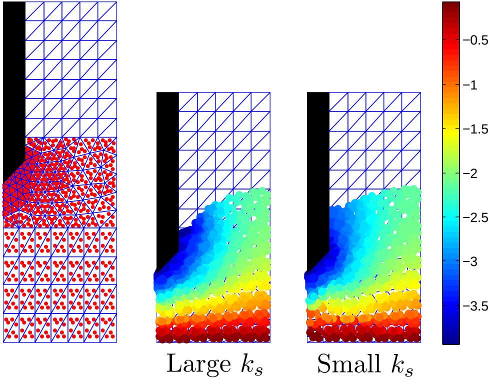
Half of geometry is used.
Colours show the vertical displacement.

The stress-displacement for the 'zero-thickness interface element' is given by

$$\begin{Bmatrix} \tau_s \\ \sigma_n \end{Bmatrix} = \begin{bmatrix} k_s & 0 \\ 0 & k_n \end{bmatrix} \begin{Bmatrix} w_s \\ w_n \end{Bmatrix},$$

where

- w_s and w_n are tangential and normal relative displacements,
- k_s and k_n represent the tangential and normal stiffness per unit length along the interface.



Colours show the vertical displacement.

Conclusions

- Using the MPM to model pile installation,
- Given rotation angle and axial displacement of installation, our program will compute the torque and reaction force ,
- Contributions:
  - translating and rotating mesh,
  - interface element for pile-soil interaction.