Numerical modelling of screw pile installation for wind energy foundation systems

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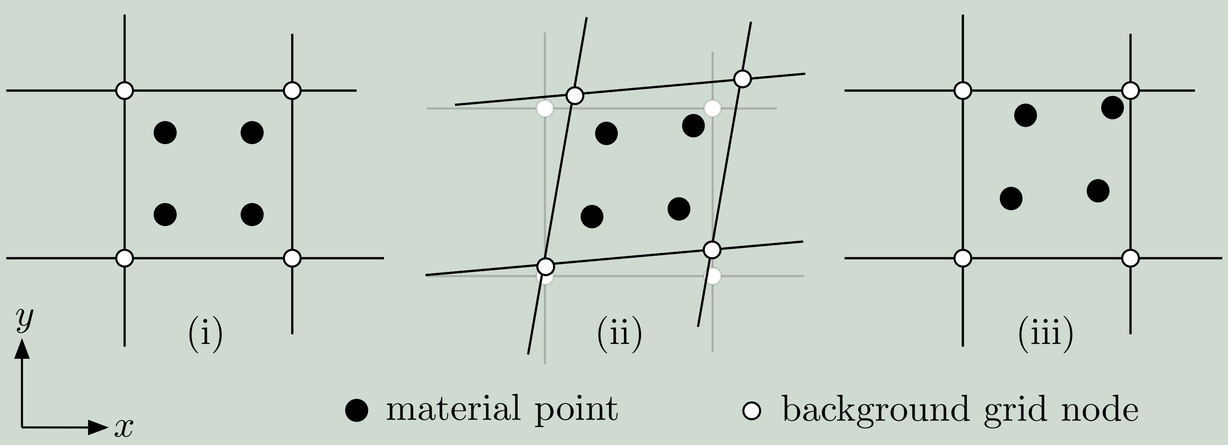
Computational geomechanics

- Computational geomechanics problems typically contain very large deformations, highly non-linear material behaviour and are often truly three-dimensional; these are challenging problems to tackle with numerical methods.
- The finite-element method is the *de facto* numerical simulation tool used in engineering however, it struggles to cope with very large deformations and/or fracture.
- The Material Point Method (MPM) is an alternative method that has the potential to be successful in these areas.

Material Point Method (MPM)

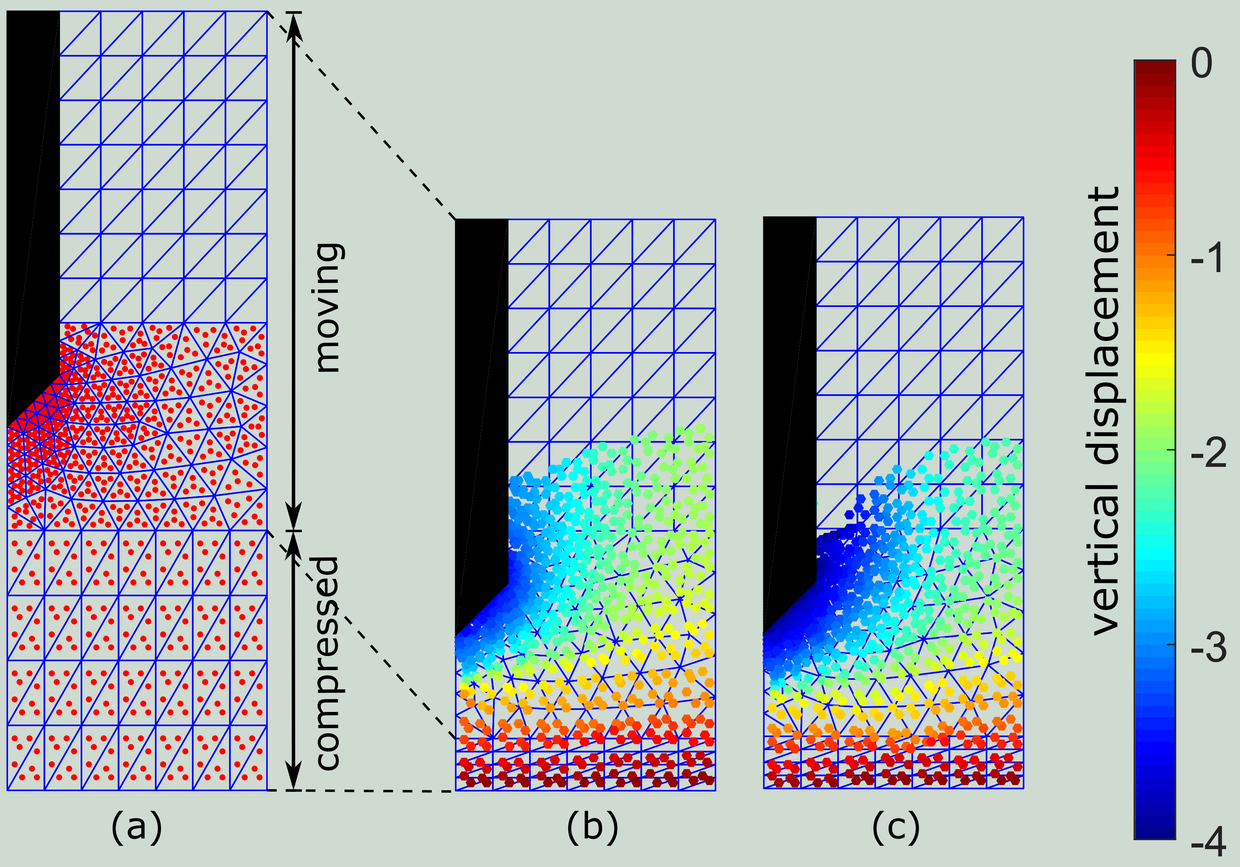
- The physical domain is represented by a series of points (material points).
- Numerical calculations are performed on a regular background grid.
- Physical information (stress, strain, etc.) is stored and carried at the material points and mapped to the background grid.



MPM numerical steps: (i) transfer information to the grid; (ii) calculate displacements & map to points; and (iii) reset grid & continue.

Challenges and our approaches

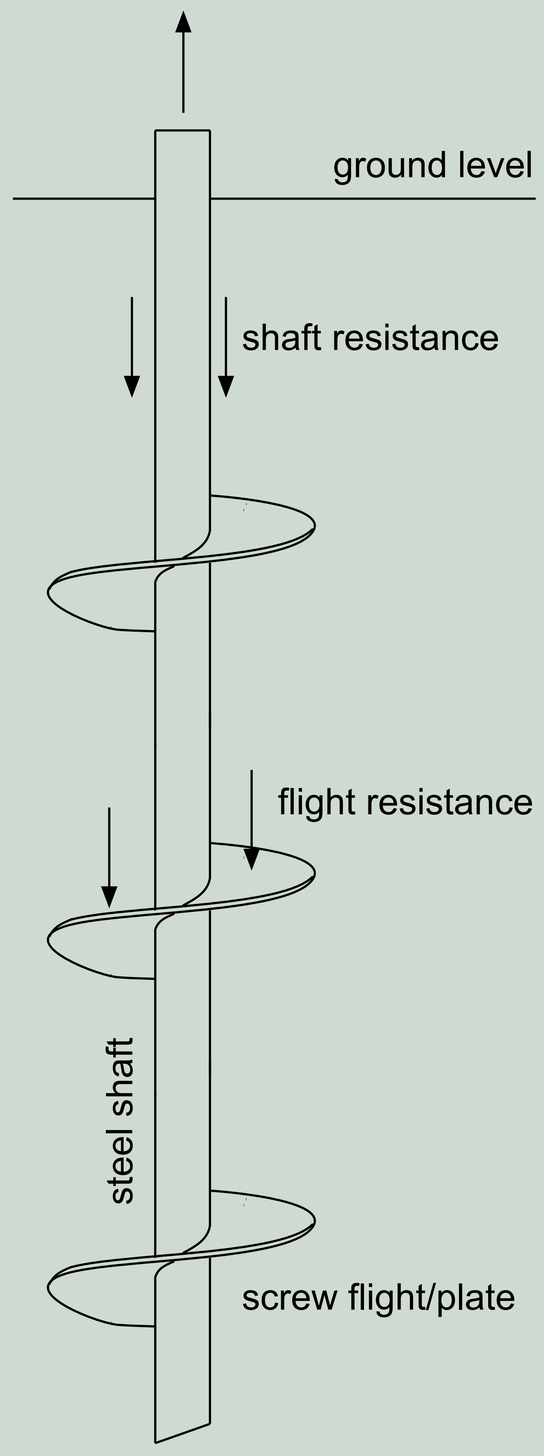
- Imposing boundary conditions (fixed displacements) that do not coincide with the background grid is challenging in the MPM. This is illustrated by the problem of pile installation (see figures below).
- We use a moving mesh, which is attached to the pile.
- To model the pile-soil interaction, we employ a frictional interface with an elasto-plastic material model.
- An *implicit* implementation of the MPM has been developed, with more stability and accuracy than an *explicit* approach.
- Our implementation includes both material (plasticity) and geometric (large deformation mechanics) non-linearity, for better modelling of the actual mechanical behaviour of soil.



A 2D model for pile installation using half the geometry due to symmetry. The black region indicates the pile. (a) initial setup showing grid (blue) and material points (red); deformed profile with a frictional pile-soil interface using an elasto-plastic model, the frictional coefficient in (b) is less than in (c).

Screw pile installation

- Screw piles are foundations which are screwed into the ground and are widely used onshore, one example being to support motorway signs and gantries:
  - however, they have yet to be proved as an offshore renewable foundation system; and
  - due to 2050 energy targets the UK needs commercially viable wind turbine foundation solutions in deeper waters.



screw pile installation & load-resistance components

- Very challenging problem to model numerically due to:
  (i) very large deformations, (ii) non-linear material behaviour,
  (iii) truly three-dimensional and (iv) complex soil-structure interactions.

Installed capacity

- Soils *remember* what has happened to them - modelling the installation is key in understanding the disturbed *state* of the soil after pile installation.
- Disturbing the soil can significantly change the load-displacement response and capacity of the installed pile.
- MPM results will be mapped to conventional finite element-based analysis for long term cyclic capacity.
- **Want to know more?**
  `www.screwpilesforoffshorewind.co.uk`

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