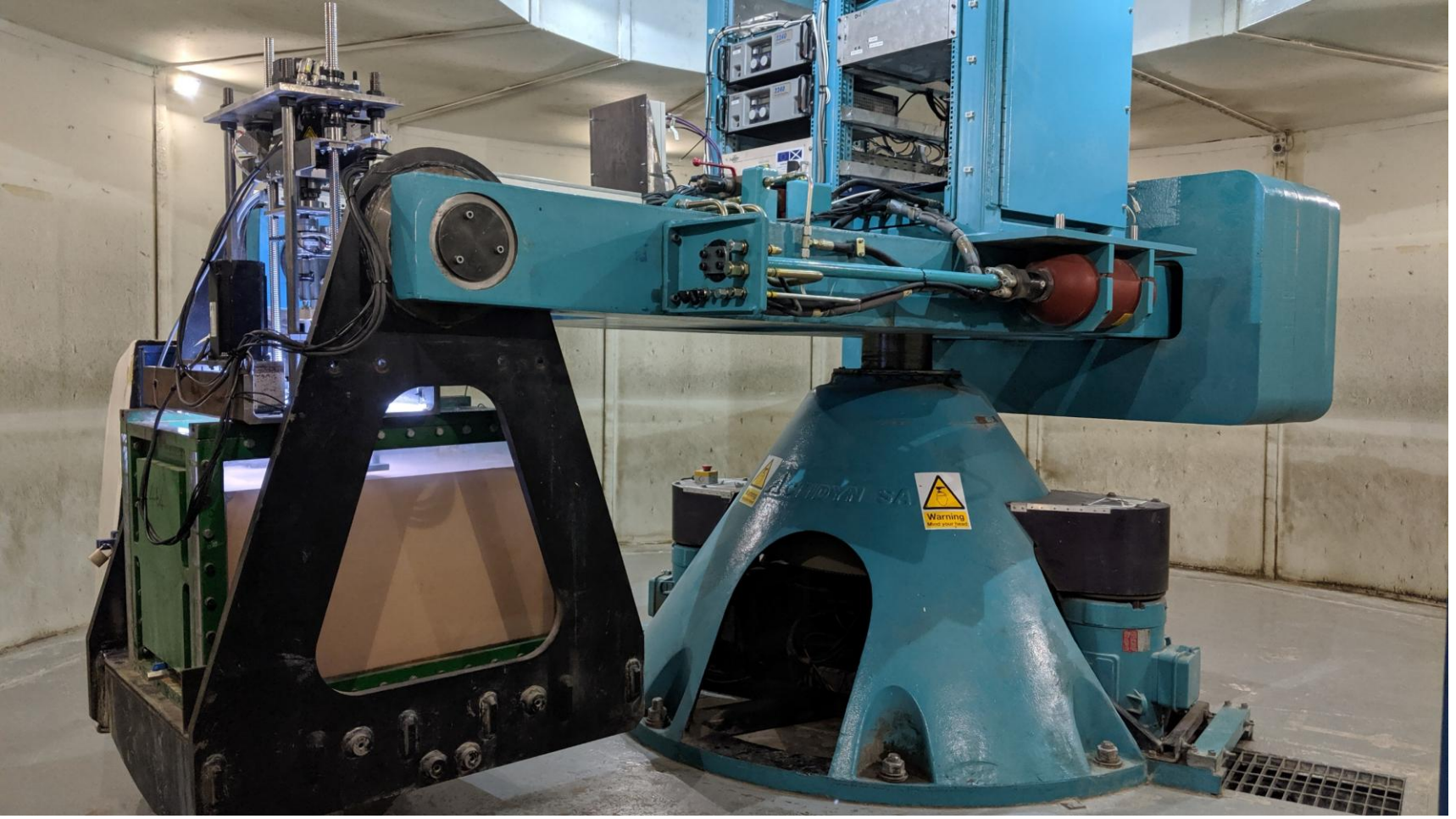


OHL Foundation Uplift: redesigning overhead line foundations with reduced carbon impact

Mr Stuart Flint| SSEN Transmission

Prof Michael Brown| University of Dundee | 5th November 2025

Contents

- Challenge to reduce CO_2 in buried foundations
- What are we doing to improve and why?
- How have we investigated and validated improvements
- 3 different improvement strands
- What we have achieved
- What can we do to improve further?

Overhead Line (OHL) Foundations - scale of upgrading in the UK

"Great Britain is about to embark upon the biggest change to the electricity network since the high voltage transmission grid was established back in the 1950s," it said.

Its latest £58bn estimate is for work needed between 2030 and 2035 and comes on top of a previous £54bn estimate for work taking place between now and 2030.

https://www.bbc.co.uk/news/business-68601354

the electrical motorway that transports power around the country. This ingenious network of specialist equipment is made up of 7,000km of overhead line, 300 substations and 22,000 pylons, which comprise the physical infrastructure of the electricity system.

https://www.nationalgrid.com/electricity-transmission

90,000 pylons

There are over 90,000 pylons in the UK.

Next time you're in a car or on a train, see how many pylons you can see out of the window! 13 Apr 2024

https://www.funkidslive.com

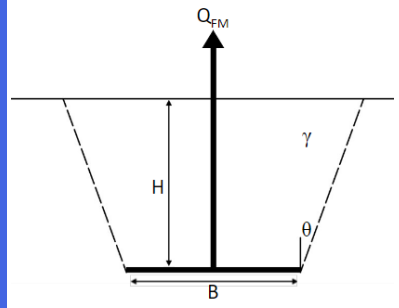
By 2030, SSEN alone are set to construct over 7000 OHL foundations

What is the challenge?

- Significant number of new and replacement OHL structures required (6000 plus)
- Upgrading network - new foundation uplift loads
- Existing structures coming to end of life
- Minimising CO_2 generation and primary resource use.
- Reduce embodied CO_2
- Remote access and important habitat
- Industry may be understandably risk adverse and confidence is required to make design practice changes

What are we doing about it?

1. Are our design methods fit for purpose?

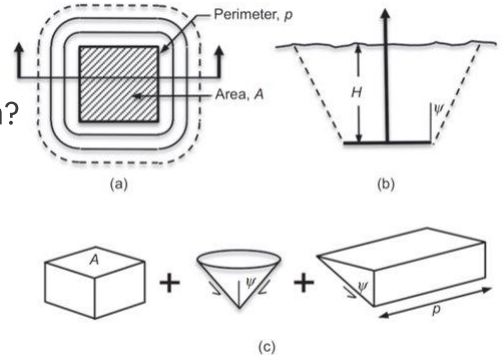


"The frustum method does not attempt to represent the actual failure mechanism in the soil. The actual failure mechanism is complex ***and is likely to follow the vertical construction interface between backfill and surrounding soil*** *and will include friction effects along this interface."*

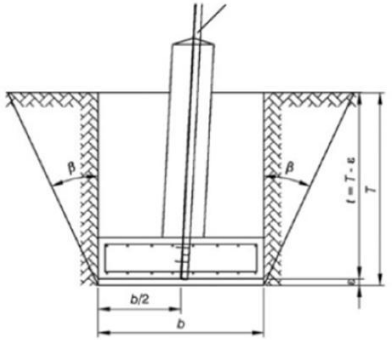
National Grid TS 3.4.15 (2018)

1920's based approach?

2019 based approach?

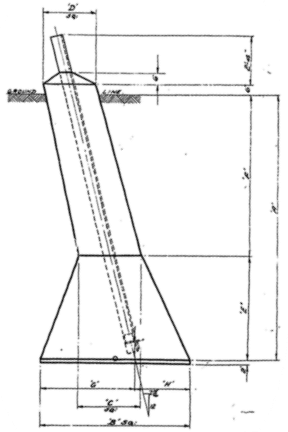


2. Can we minimise/reduce material use?



Go back to pyramids?

Less concrete?



3. Can we use fast build alternatives

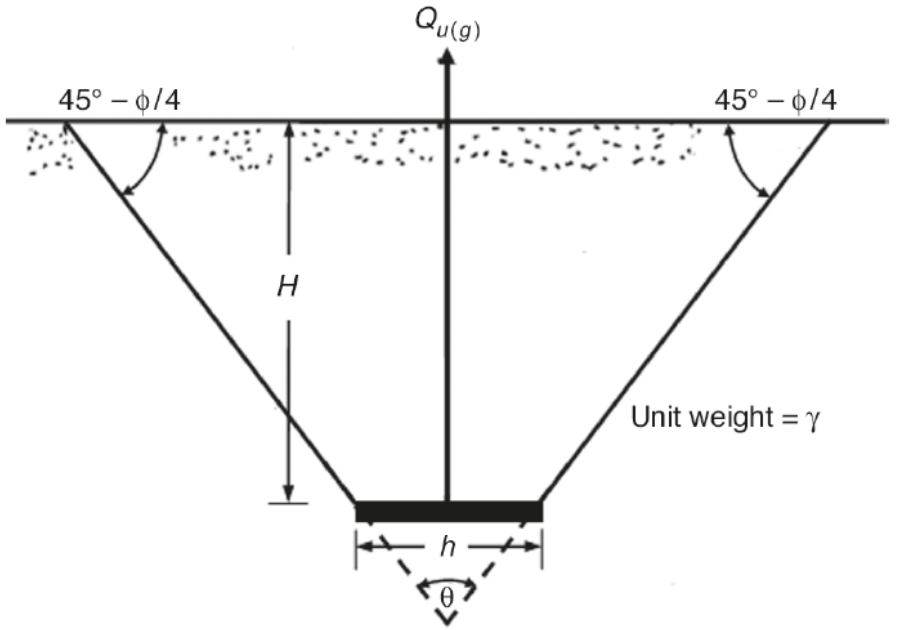
Do away with concrete?

Bolt together grillages?

UK dropped out of favour 1960s

1. Current Uplift Capacity Calculation Method

- Weight of assumed frustum of soil above foundation only
- **Dates back at least to Pannell (1926)**
- Wedge angle based upon?
- Shear strength on failure surfaces ignored (conservative?)
- Current standards acknowledge shortcomings:



"The frustum method does not attempt to represent the actual failure mechanism in the soil. The actual failure mechanism is complex ***and is likely to follow the vertical construction interface between backfill and surrounding soil*** *and will include friction effects along this interface."*

National Grid TS 3.4.15 (2018)

Parameter	Value of Standard Penetration Test for Non-cohesive materials (N)				
	N < 10	10 < N < 20		N > 20	
		Dry	Saturated	Dry	Saturated
Unit weight (kN/m^3)	N/A	18	10	19	10
Frustum angle (°)	N/A	15	15	25	25

Parameter	Value of undrained shear strength for cohesive materials, s_u (kN/m^2)		
	s_u < 35	35 < s_u < 50	s_u > 50
Unit weight (kN/m^3)	N/A	17	19
Frustum angle (°)	N/A	15	25

What did we do to investigate?

- 2D & 3D Finite element simulations (fast/cheap)
- Pad & column and Pyramid foundations
- Failure surface develops at an angle
  - some methods greatly over-estimate angle
  - closest match with **Giampa (2019)** over all densities and depths

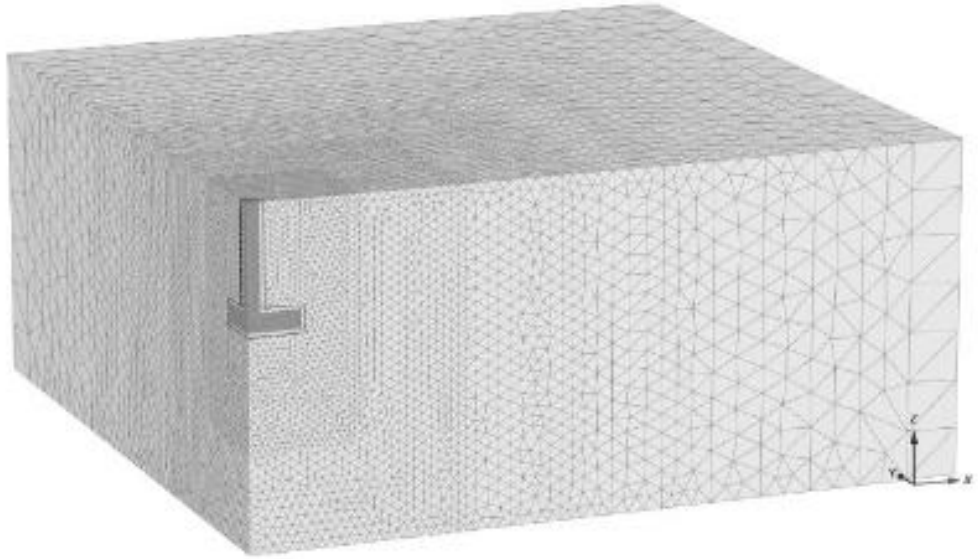
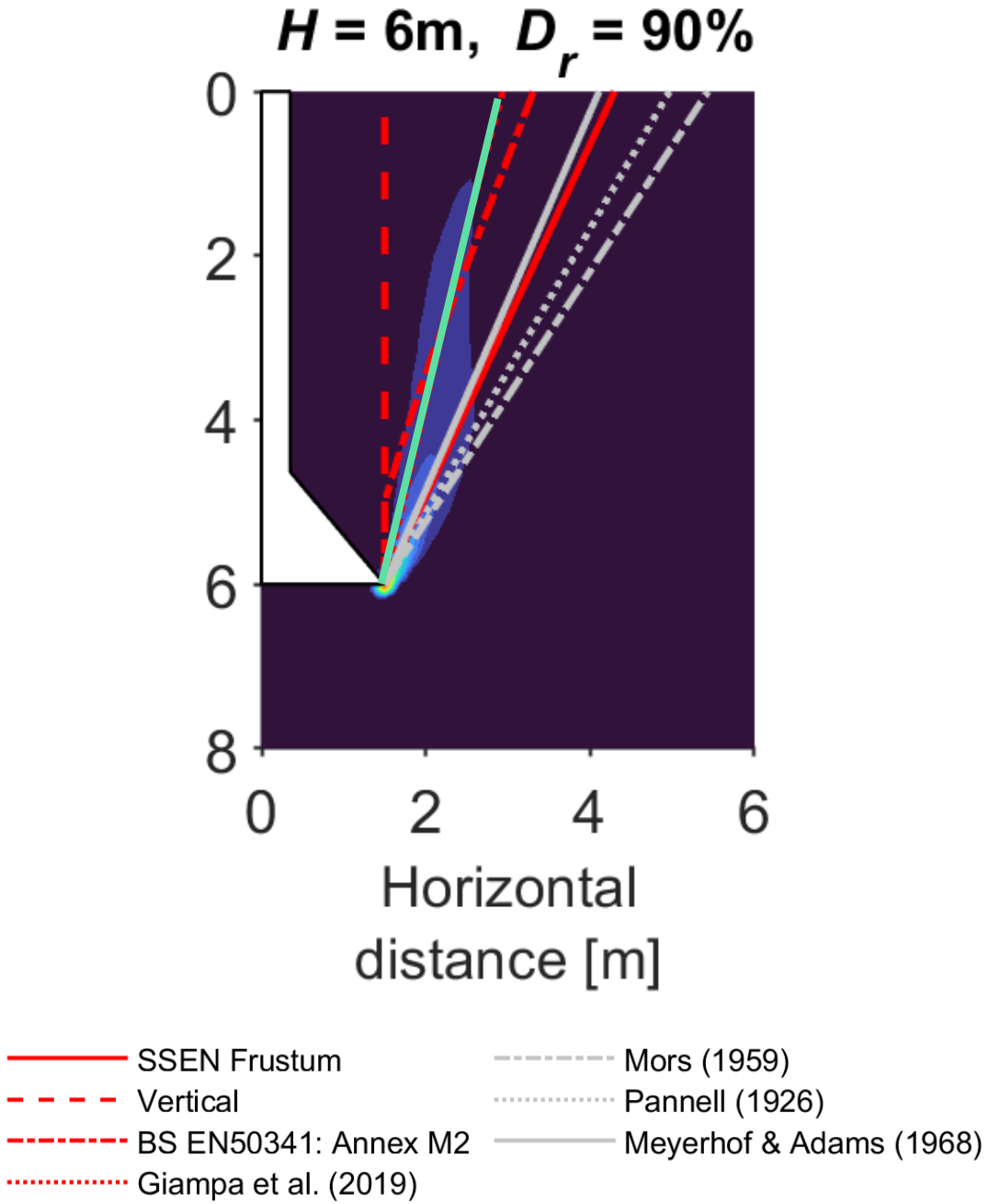


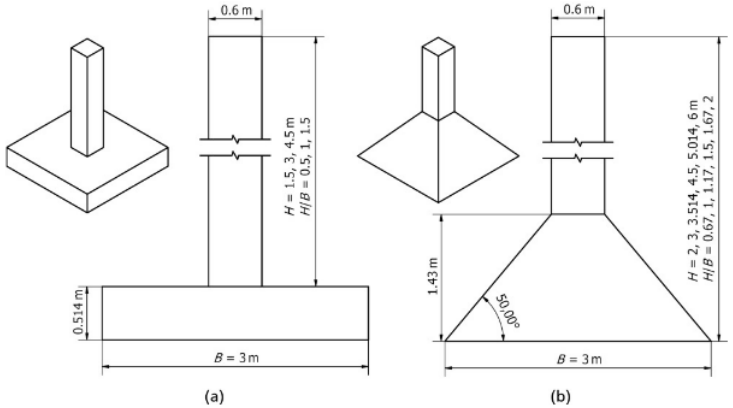
Figure 3. Example of finite-element mesh used in Plaxis 3D analyses

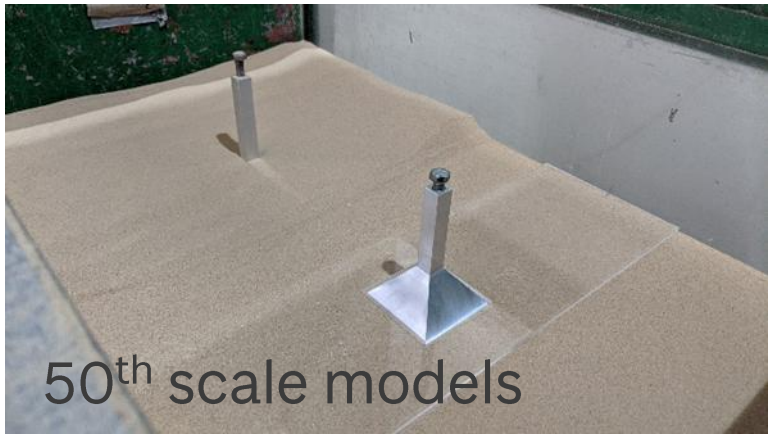


How did we validate?: Centrifuge Scaled Model tests

- Scaled modelling Validation using Geo centrifuge to validate FEA

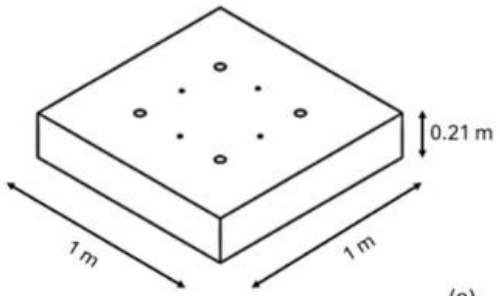
50th, 50g, 1.5 tonnes 140 RPM



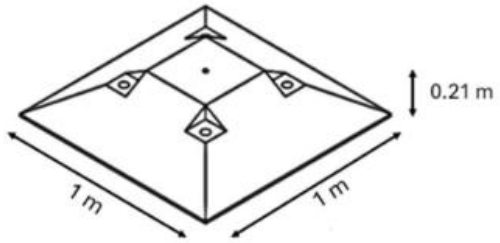


How did we validate?: Near Full Scale Model testing

- University of Bristol UKRIC SOFSI centre



(a)



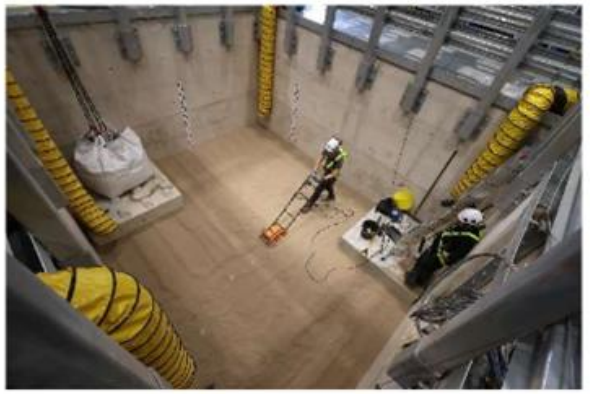
(b)


(c)


(d)

1/2 -1/3 scale foundations

(c) Sand placement



(d) Rake spreading

(e) Sand compaction

(f) Foundation placement

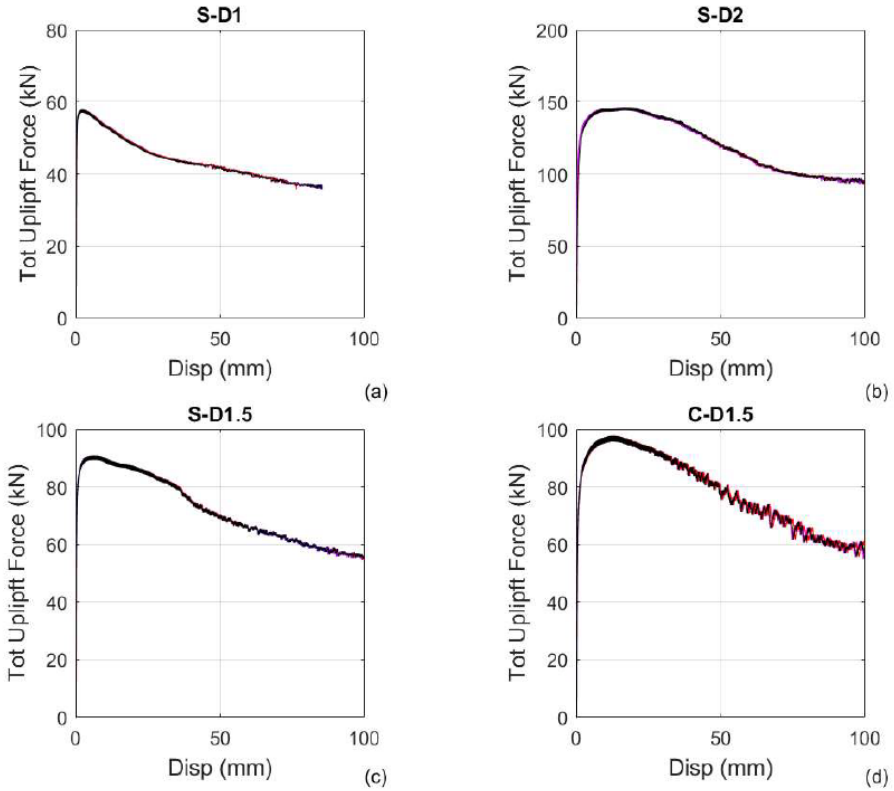
(g) Continue filling

(h) Final surface

Figure 6 Stage of sand bed preparation with embedded foundations

How did we validate?: Near Full Scale Model testing

- University of Bristol UKRIC SOFSI centre



1, Check on uplift Capacity

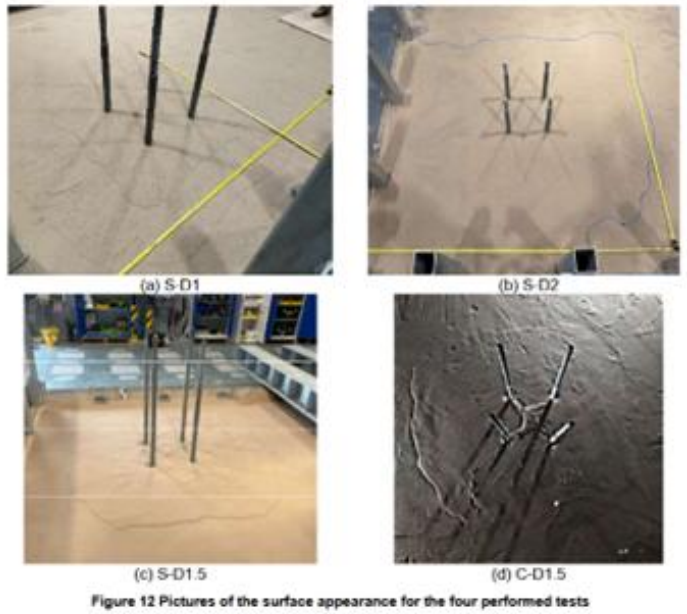
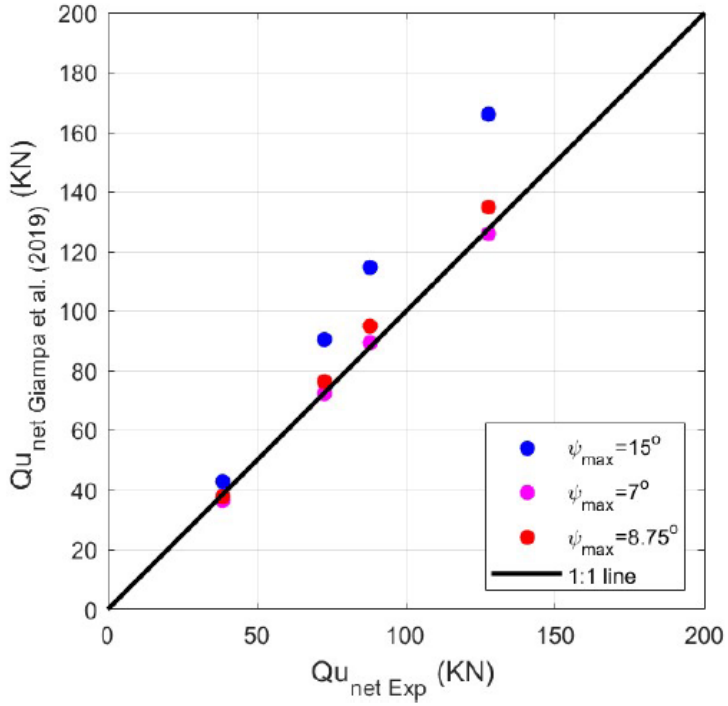


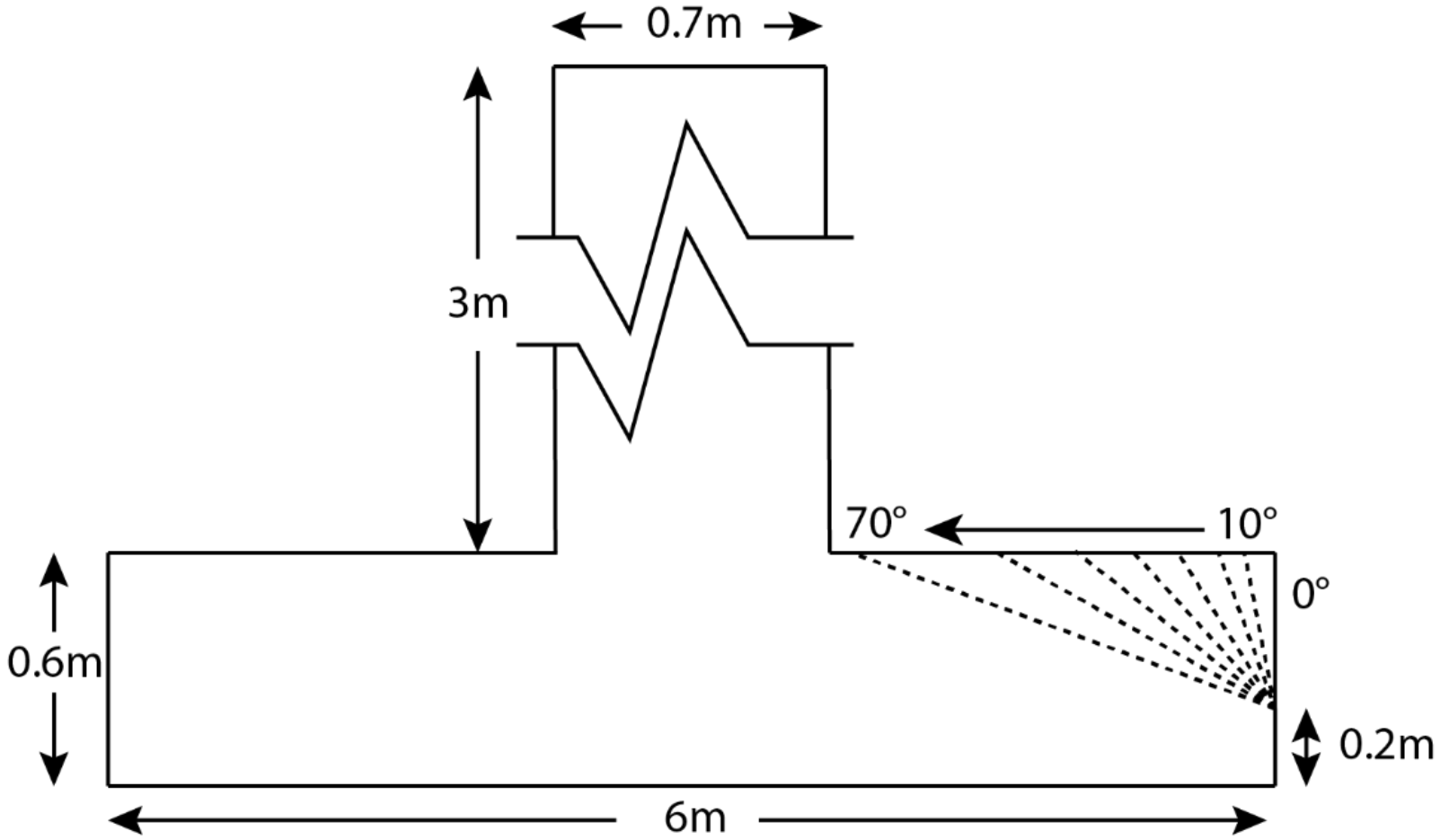
Figure 12 Pictures of the surface appearance for the four performed tests

2, Check soil mechanisms match design method



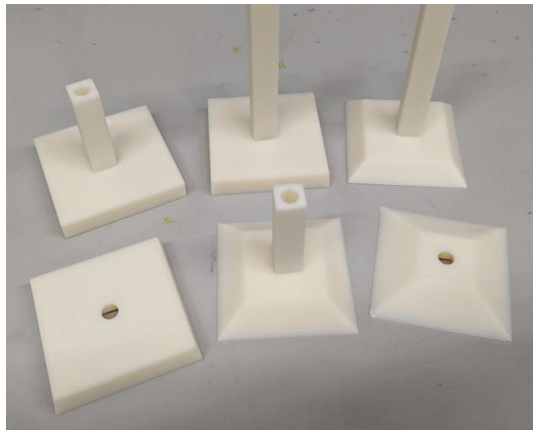
3, Check new method performs as expected

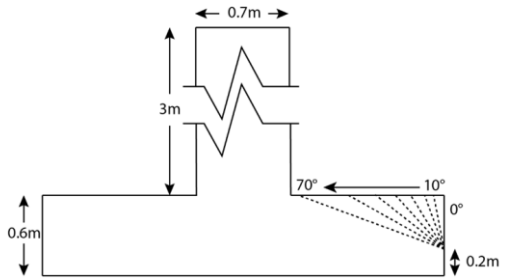
2. Refined pad design/shape-minimising concrete material

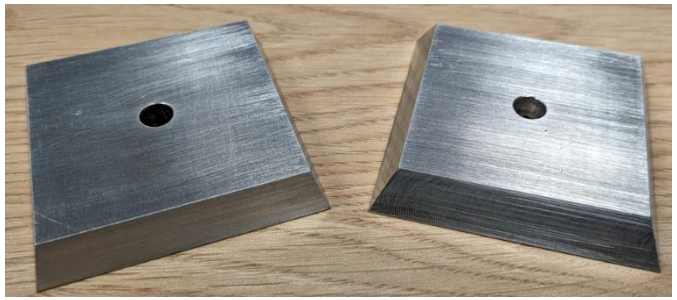


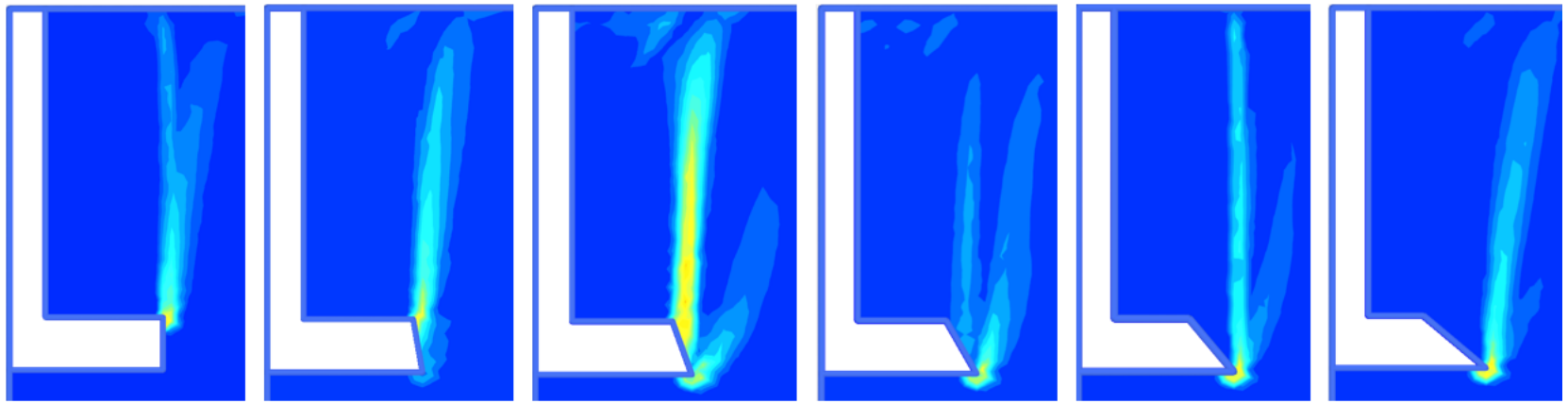
What else have we Improved?

- Foundation shape can be optimised
  - Capacity increased-smaller foundations
  - Optimised shapes require less concrete







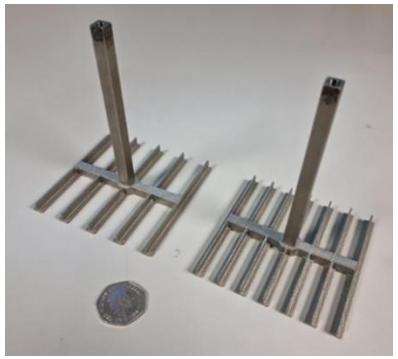


Chamfer angle	0°	10°	20°	30°	40°	50°
Volume reduction	0%	3%	10%	17%	25%	34%

90k new foundations, 50 degrees chamfer, saves 180,000 tonnes of CO_2!

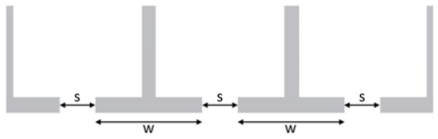
3. Can we use grillage foundations again?

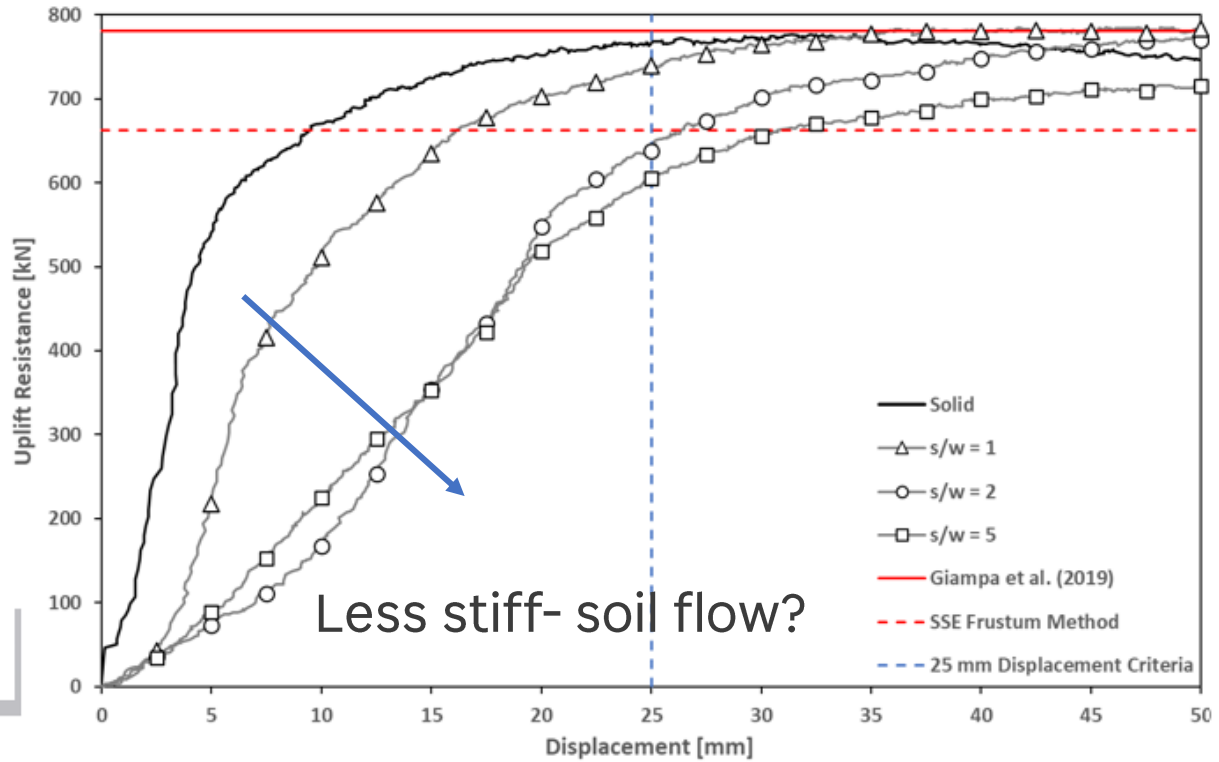
- Grillages can be used as an alternative to solid concrete foundations
  - More efficient than codes suggest for ultimate capacity
  - Stiffness not as good as solid
  - Good option for difficult to access locations- Helicopter/light weight vehicles?

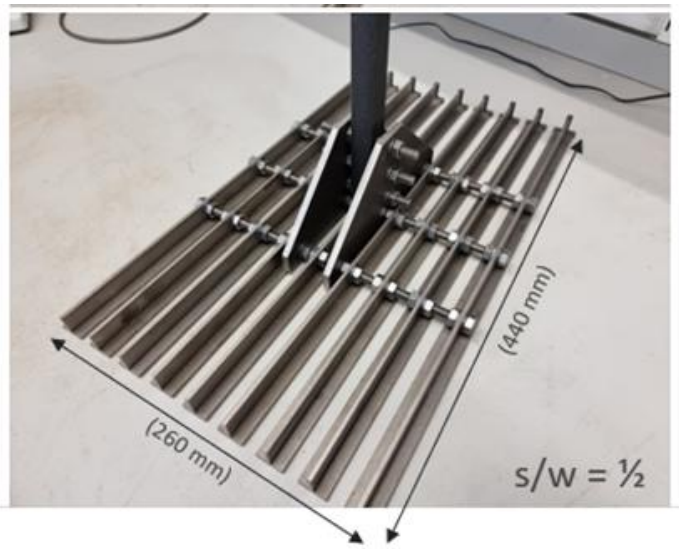


centrifuge model 28th scale

- Reduced scale models 1:28
- Spacing ratio (s/w): 1, 2 & 5 (Solid plate)
  - s: spacing between grilles
  - w: grille width (7mm)



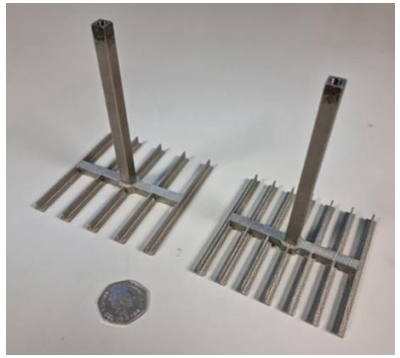




1g model 10th scale

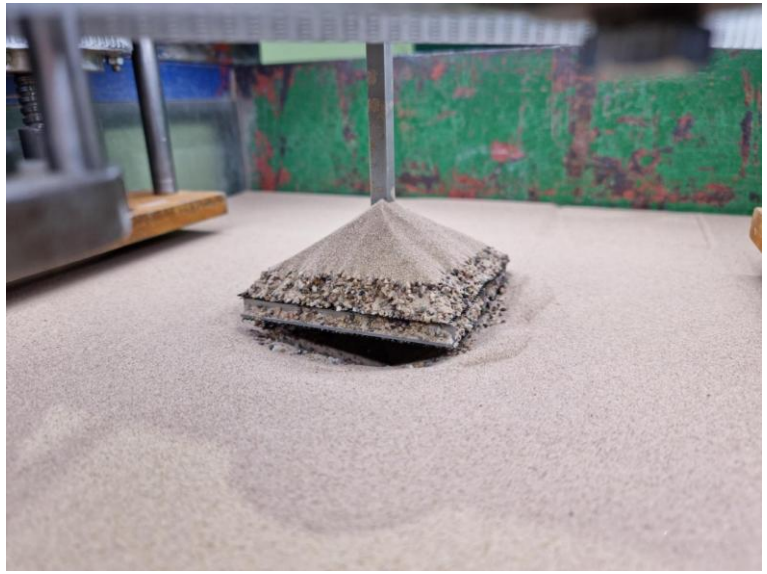
How can we improve Grillage performance?

- Integrating grillages with low-cost geogrids
  - Low-cosy way of improving performance
  - Easy transport with grillage components



Wide spaced grillage pull out test

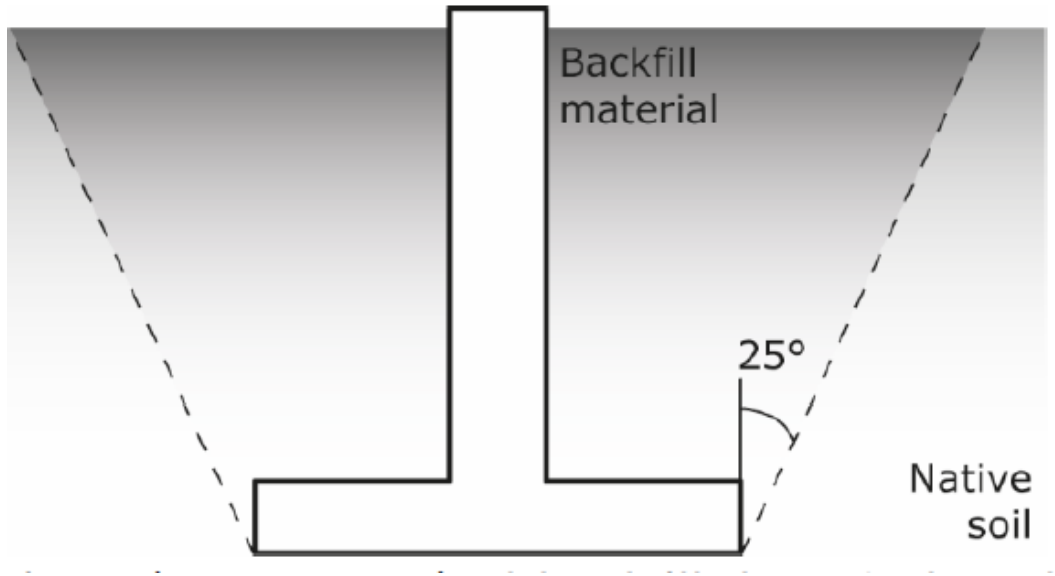
Geogrid wrapped grillages



Affect of adding geogrid

What is next?

- Can we control or optimise backfill to increase performance further?
- How do we implement in Design codes and industry specifications?
- How do we get Infrastructure owner/contractor take up/use?



Backfill optimisation modelling geometry

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Improved uplift capacity design for overhead line equipment in granular soils

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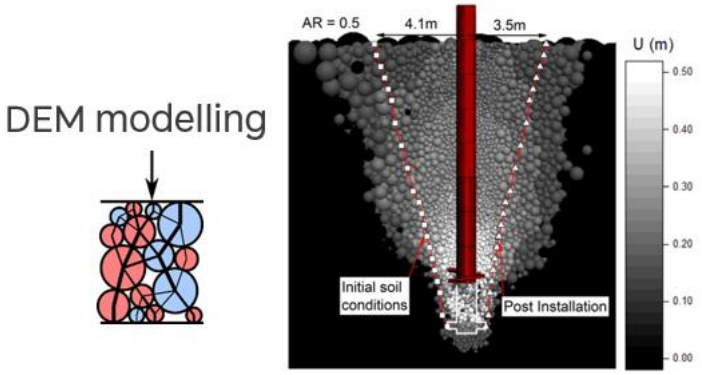
Open Access Publication in UK industry focused journals

What achieved so far, what in the future?

- Cheap, 1%- **£18.3M** to do the same testing programme at full scale/field (+CO_2 saved)
- Improved design methods could cut the number of refurbishments required
- Improved design methods could **save up to £118,000 tonnes of CO2e**
- Shaped foundations could **save up to £180,000 tonnes of CO_{2e}** alone
- Paved the way for re-introduction of concreteless foundations
- Showcased Joint Industry-Academia Innovation Journey & potential

SOFSI Large Scale Foundation testing pit- Bristol University, UK



Physical & Numerical modelling Expertise- Dundee University, UK

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- **National Grid Electricity Transmission** and **SSEN Transmission** for project support
- **University of Bristol** UKRIC SOFSI Large geotechnical testing facility

Publications (more to come!):

- **BROWN, M.J., DAVIDSON, C., SHEPHERD, C., FLINT, S. & MBISIKIE, S. (2025)** Improved uplift capacity design methods for overhead line equipment in granular soils. *Proc. Inst. of Civil Engineers: Geotechnical Engineering Journal*. DOI: 10.1680/jgeen.25.00006
- **SHEPHERD, C., BROWN, M.J., DAVIDSON, C., BECKETT, C. & FLINT, S.** (2024) Comparative assessment of 1g and centrifuge uplift tests on steel grillage foundations. *Proc. 5th ECPMG 2024 European Conf. on Physical Modelling in Geotechnics*. 2-4 October 2024, Delft, the Netherlands.
- **SHEPHERD, C., BROWN, M.J., DAVIDSON, C., BECKETT, C. & FLINT, S. (2024)** Uplift enhancement of steel grillage foundations for overhead line foundations. *XVIII European Conf. on Soil Mechanics and Geotechnical Engineering (ECSMGE)*. Lisbon, Portugal, 26-30th August 2024. pp. 3316-3320. DOI: 10.1201/9781003431749-654.