Seismic Behaviour of Onshore Wind Turbine Foundation on Liquefiable Soil

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Research Motivation

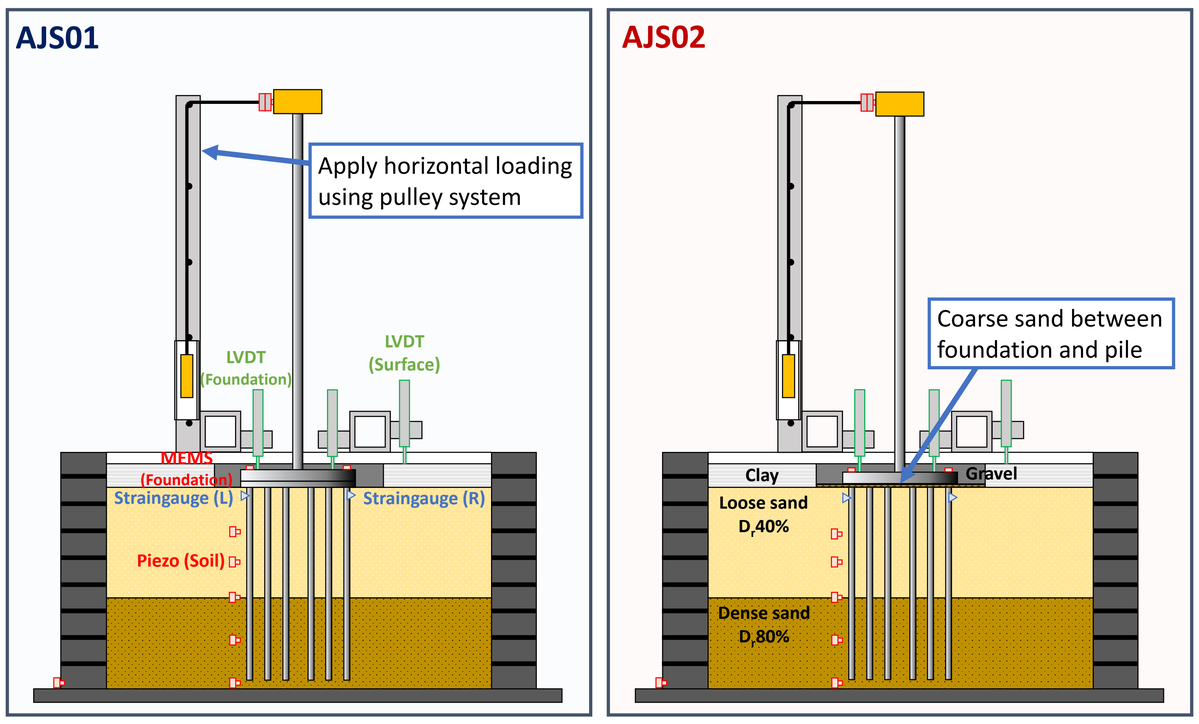
- ❑ As the wind energy industry expands to the seismically active part of the world, ensuring the seismic capacity of the wind turbine becomes an important issue.
- ❑ Wind turbine's tall and flexible structural characteristics make it highly susceptible to both structural acceleration and settlement by the earthquake

Motivated by an industry project, this research aims to study the effect of foundation condition toward the acceleration and settlement of onshore wind turbine on liquefiable soil. The ultimate goal is to **establish optimised design practice** for foundations seismic capacity.

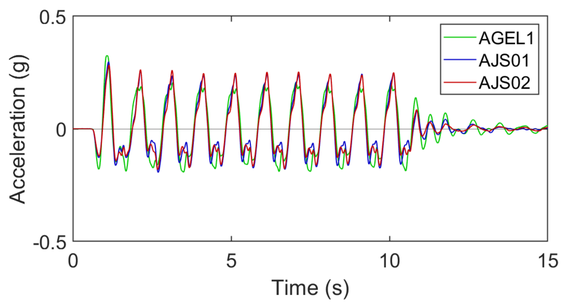
Test Methodology

❖ Geotechnical Centrifuge test schematics

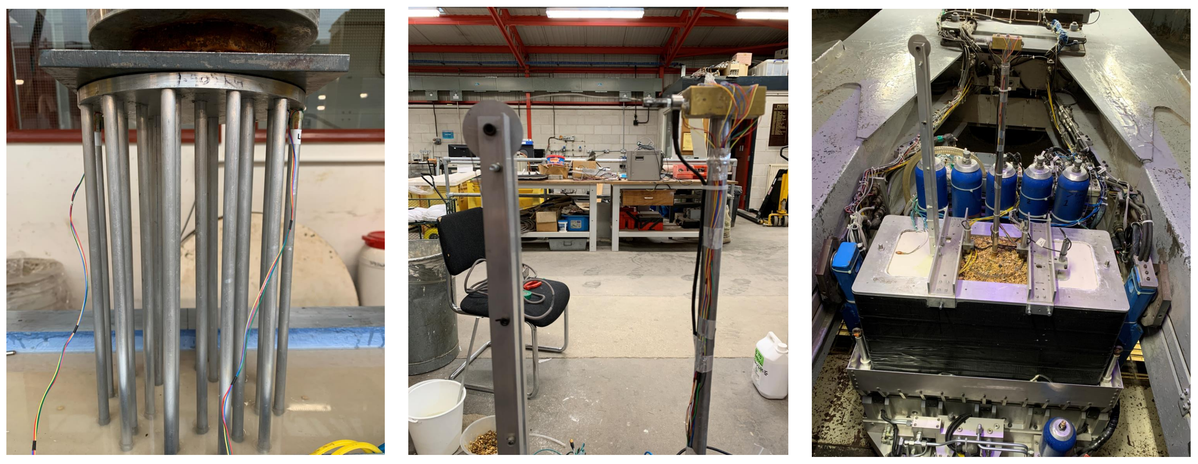
- ❑ Conducted three geotechnical centrifuge tests at 80g
  - **AGEL1 :** Comparison group **without horizontal load and group pile**
  - **AJS01 : Piled raft** foundation composed of 25 piles
  - **AJS02 :** Raft foundation **sit on top of disconnected pile group**
- ❑ Pile dimension (L) 26 m × (d) 0.8 m, embedded 13m into the dense soil layer.



❖ Input dynamic loading



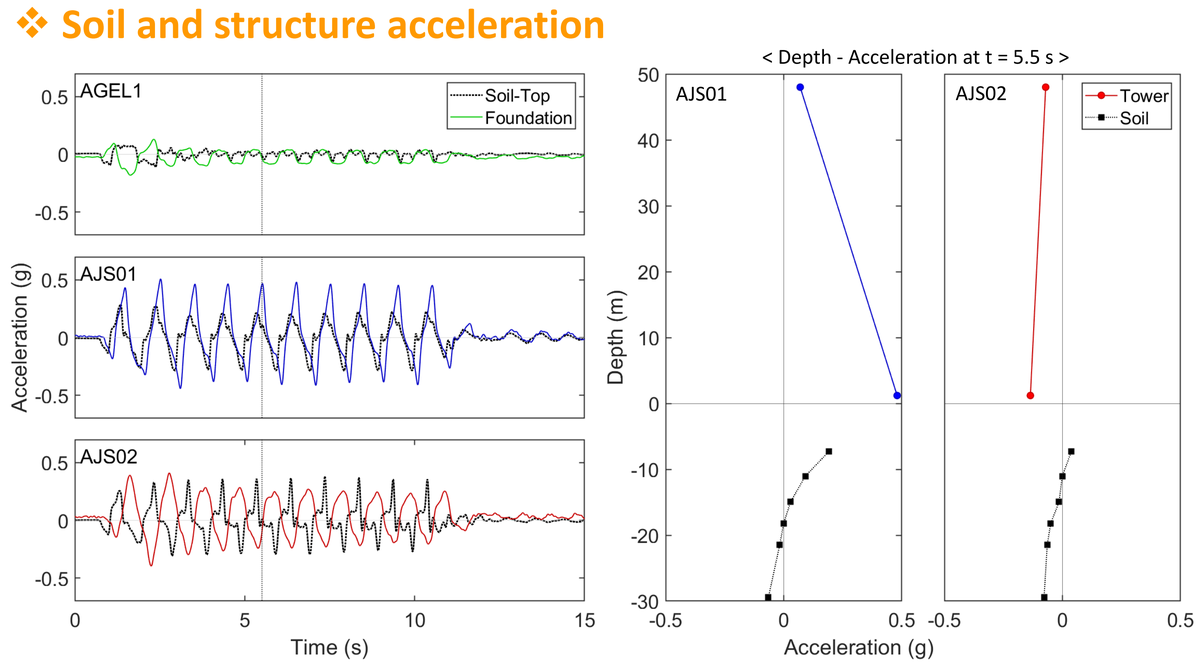
- ❑ **1Hz sinusoidal loading, 10 cycle**
- ❑ Represents low-frequency component of earthquake loading
- ❑ Loading frequency is much higher compare to the **structure natural frequency (0.3Hz)**



(Left) Pile group installation using hydraulic piston
(Centre) Pulley system attached to the tower head
(Right) Finished test setup mounted on the centrifuge

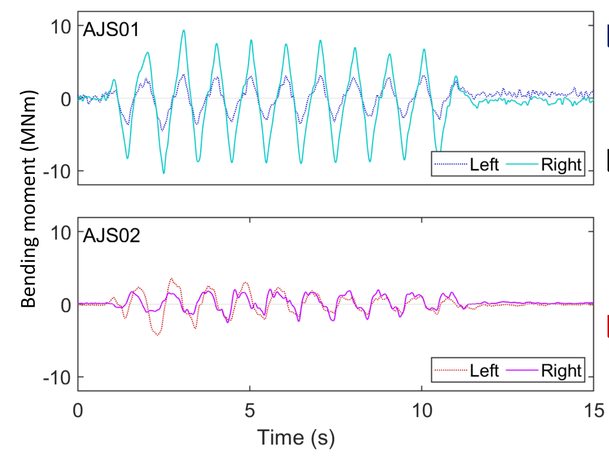
Test Result

❖ Soil and structure acceleration



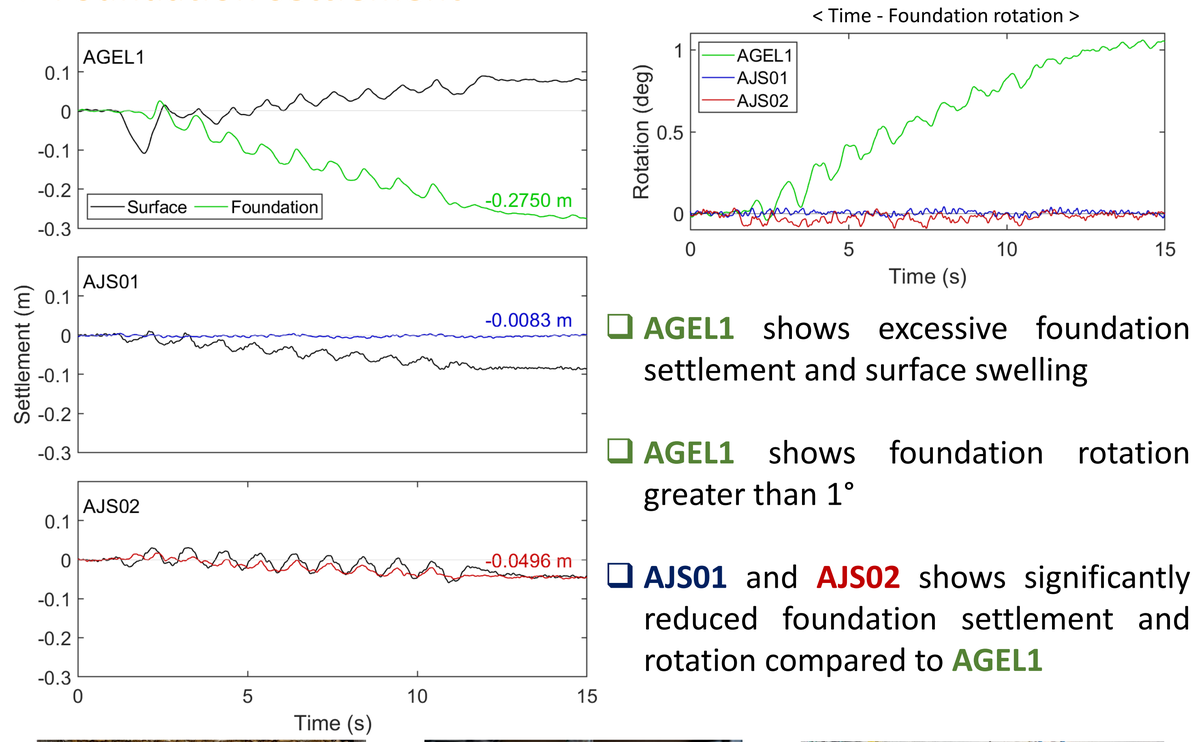
- ❑ **AGEL1** does not show clear acceleration due to the soil liquefaction
- ❑ **AJS01** and **AJS02** show noticeable acceleration in both soil and structure
- ❑ **AJS02** foundation acceleration decreased and was out of phase during earthquake

❖ Pile Bending moment



- ❑ **AJS01** shows larger bending moment compared to **AJS02**
- ❑ Bending moment is larger at the right side as the rotational axis is biased due to the horizontal load
- ❑ **AJS02** shows noticeable but smaller bending moment

❖ Foundation settlement



- ❑ **AGEL1** shows excessive foundation settlement and surface swelling
- ❑ **AGEL1** shows foundation rotation greater than 1°
- ❑ **AJS01** and **AJS02** shows significantly reduced foundation settlement and rotation compared to **AGEL1**

(Left) Mark left by foundation settlement in **AGEL1**
(Centre) Soil-foundation gap caused by surface settlement in **AJS01**
(Right) Pile group after earthquake in **AJS02**

Conclusion

- ❑ Wind turbine foundation on liquefiable soil needs to be reinforced with piles to protect the turbine from the earthquake settlement.
- ❑ Piled raft foundation shows strong seismic response during the earthquake. However, using disconnected pile can reduces the foundation acceleration.
- ❑ Disconnected pile has an advantage over traditional piled raft in reducing seismic response while retaining its capacity on mitigating the settlement

Future Work

- ❑ Parametric study supported by centrifuge test and numerical modelling
  - Additional test with different gap condition for disconnected pile
  - Optimised parameter for group pile dimension, Pile length, penetration depth
- ❑ Liquefaction mitigation using porous pile material : Combining pile and vertical drain