Installation of Large-Diameter Monopiles:

Current practice and challenges

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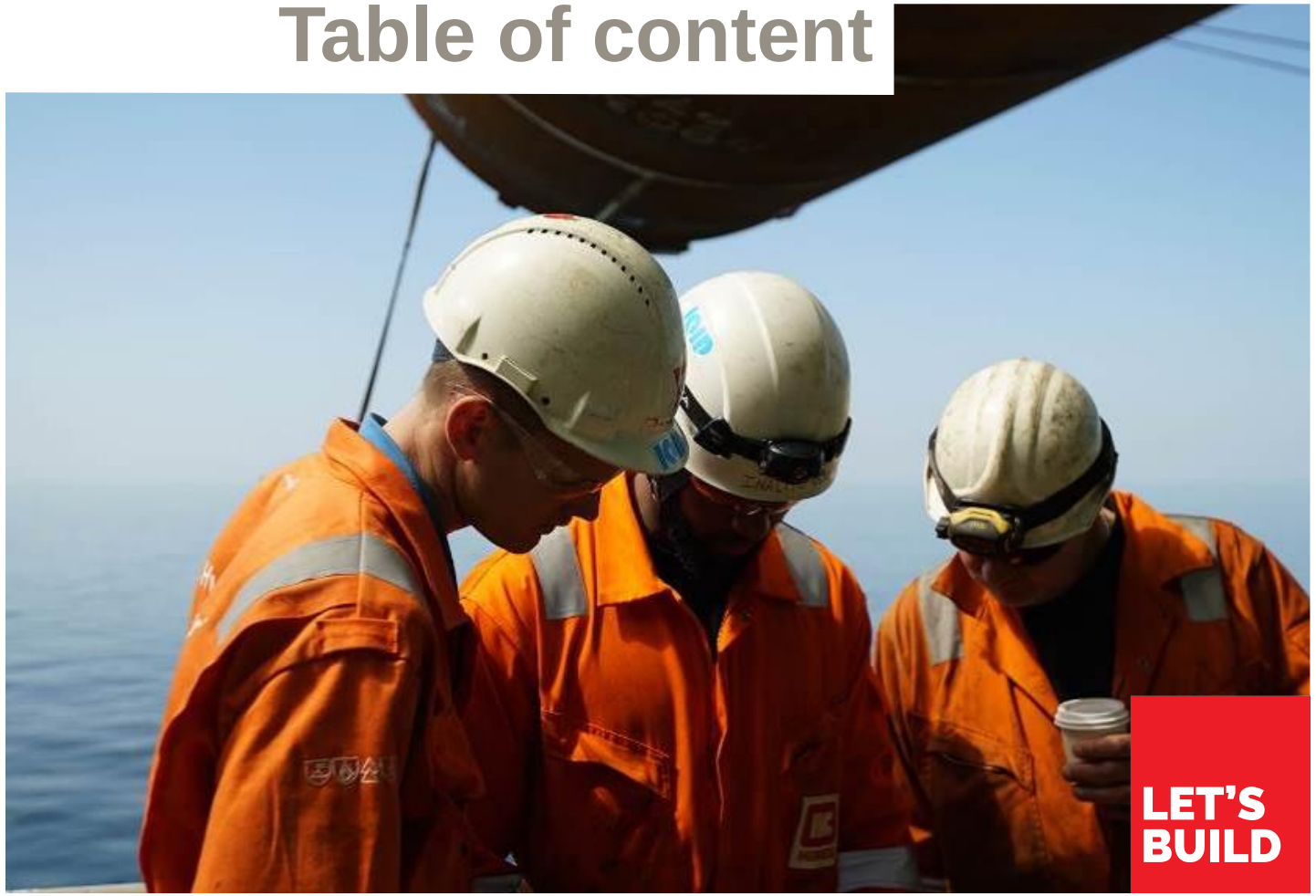


STATE-OF-THE-ART & TRENDS

STATE-OF-THE-ART

For current generation of wind turbines:

- Monopile used for water depths up to 40 meter; for larger depths jackets are used
- Monopile size in Europe more or less consolidated:
  - bottom diameter 8 m, pile top diameter 6.0 - 6.5 m

TRENDS

- In China top diameters up to 7 m are used already, in Europe 1st 8.5 m bottom designs pop up
- In US larger water depths are interesting, too. Monopile applicability will be explored again
- For next generation of wind turbines (up to 15 MW, 2025), larger pile diameters will be needed
- Pile manufacturing plants prepare for piles up to 12 m diameter

CONCLUSION

- Larger piles need to be driven in coming decade!

FACING THE FUTURE

HARDWARE

- IHC IQIP's equipment (almost) ready to drive 10 m piles:
  - First driveability studies show that S-4000 hammer will be able to drive most 10 m diameter piles
  - For specific cases, S-5500 will be needed
  - New NMS available for piles up to 8.8 m

CHALLENGES

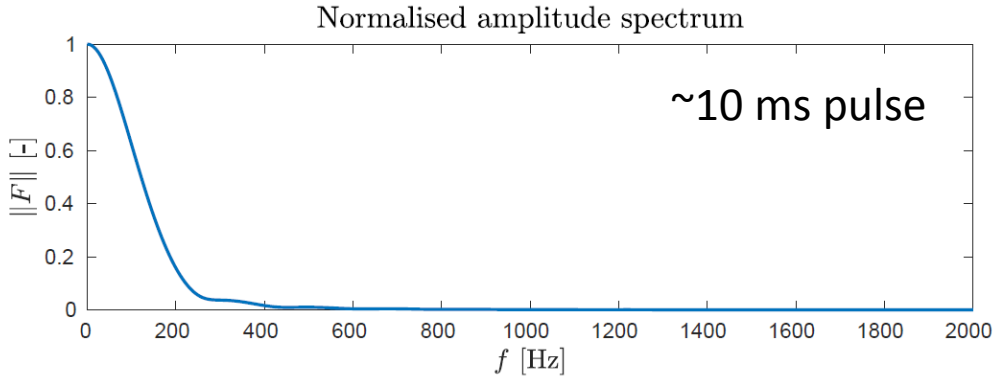
However, dispersion and accompanying deformation modes potentially (!) do bring some new challenges:

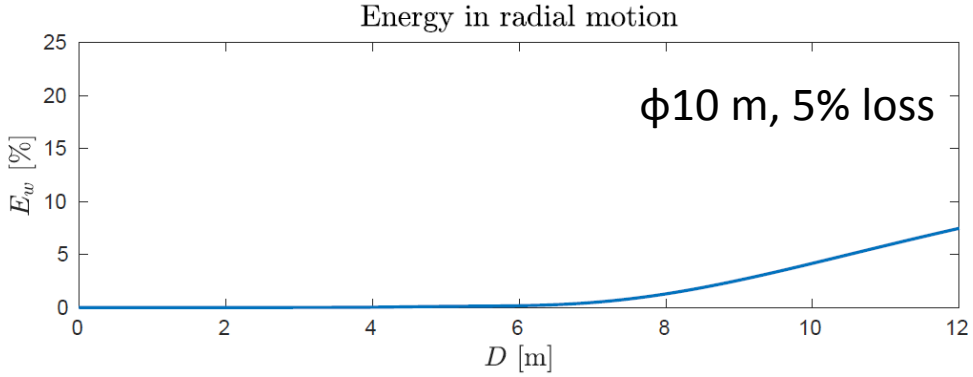
1. Pile may act as stronger noise source
   - Noise radiated into water can be captured by NMS, however, soil-born noise may also increase
2. Reduced efficiency by energy lost in the "ringing modes"
3. Increased fatigue damage by deformation involved in the "ringing modes"

QUESTIONS…

For the time being, the ‘new’ phenomenon primarily raised questions:

1. What fraction of hammer energy is lost in the “ringing modes”? Example by Peter Meijers:





2. What is the mitigation effect by the water and soil columns surrounding the pile?
3. What could be the effect on driveability?
   - E.g. will soil follow the rapid radial pile motions or not? Shaft friction may be affected
4. What is the magnitude of the stress cycles induced by the “ringing modes”?
5. Will the pile indeed act as a stronger noise source?

RELATED RESEARCH

IN-HOUSE RESEARCH

IHC IQIP is currently studying 'Pile Installation Optimization' tools, targeting at **minimum installation time** while complying to pre-set **noise and fatigue thresholds**.

In the study:

1. Real-time fatigue damage predictions up to ultimate penetration – driveability models involved
2. Soil – Structure Interaction
3. Pulse shaping, i.e. tuning the impact force versus time

RELATION TO RINGING

- The first part of this study at least helps to judge the effects of dispersion
- Pulse shaping currently envisaged to reduce both noise and fatigue
  - Sufficiently powerful to shift the 'hammer spectrum' outside away from the ring frequency?

CONCLUSIONS

- EUROS message on dispersion and ringing: Point taken, new challenges ahead
  - ‘Frequencies of risk’ to be sorted out in detail
- Incorporating the effect of soil and water may be next scientific challenge
- Development of improved driveability software – including dispersion effects – is also (scientific?) challenge
- Mitigation strategies to be explored
  - Pulse Shaping seems most promising

LET'S BUILD TOGETHER AND SHAPE THE WORLD OF TOMORROW