Design and production methods for sustainable and cost-effective wind turbine foundations

Wind Power Research in Focus 2022

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Wind farm, Markbyggden Piteå

Design and production methods for sustainable and cost-effective wind turbine foundations

Part of SWPTC's project *Methods and material for sustainable and cost effective structural supporting systems for wind power plants*

2019-2022

Partners:

- Chalmers
- NCC
- Modvion
- Tension Cam
- Stena Renewable
- Rabbalshede Kraft

NCC and Chalmers working packages:

- Wind turbine foundations
- Design loads and design optimization
- Improving sustainability and performance during construction and service life

Design and production methods for sustainable and cost-effective wind turbine foundations

PART 1

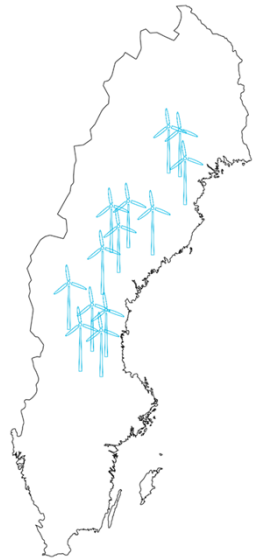
- Recent and future trends – design and environmental impact
- Sustainability-driven design optimization of foundations

PART 2

- Production and life cycle performance – interview study
- Production and life cycle performance – case study

The analysed wind farms

- 13 wind farms (1 094 turbines)
- Total installed power: 5.1 GW



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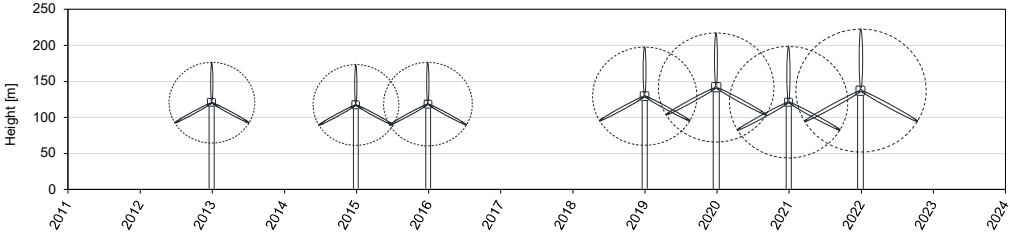
Evolution of turbine technology



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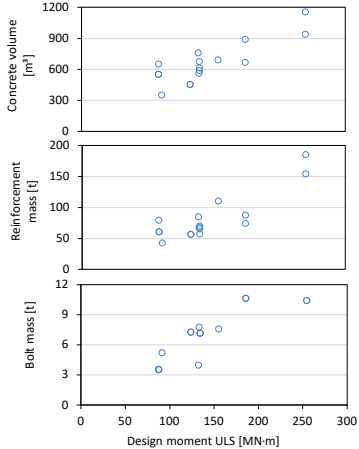
Material quantities for gravity foundations

Concrete volume: 350 m^3 – 1150 m^3

Reinforcement mass: 42 t – 185 t

Bolt mass: 3.5t – 10.6 t



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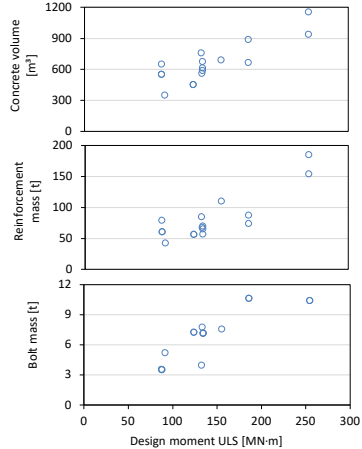

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Material quantities for gravity foundations

Concrete volume: 350 m^3 – 1150 m^3

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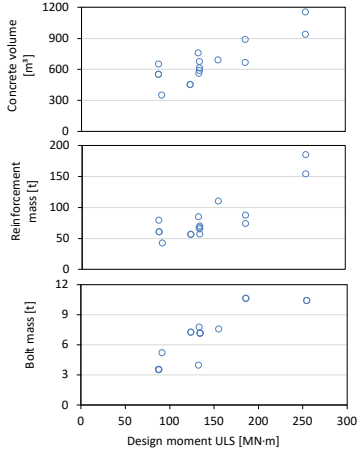
Total mass of foundation up to 3000 t

≈ 75%
of total mass for a turbine



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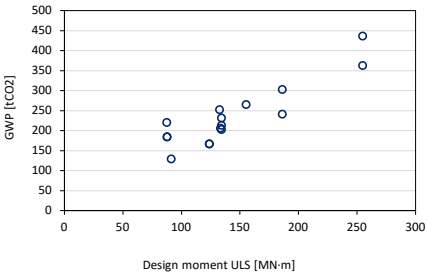
Environmental impact of foundations

- Global Warming Potential (GWP) calculated with Environmental Product Declarations (EPD)



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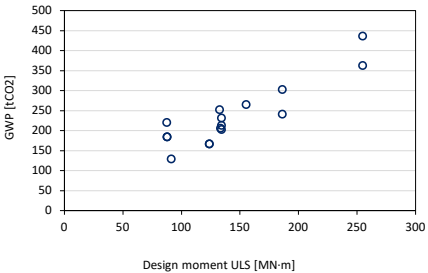

≈ 15%
of total GWP for a turbine

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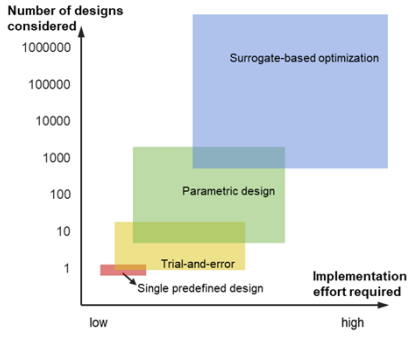
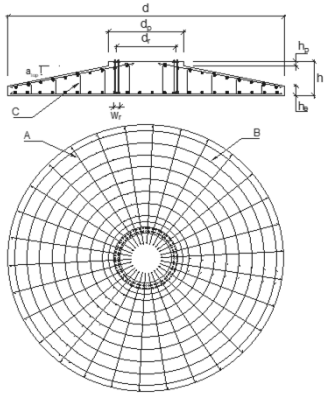
Multi-objective optimization of wind turbine foundations

- Study of the influence of a more extensive exploration of the design space under identical design constraints and criteria





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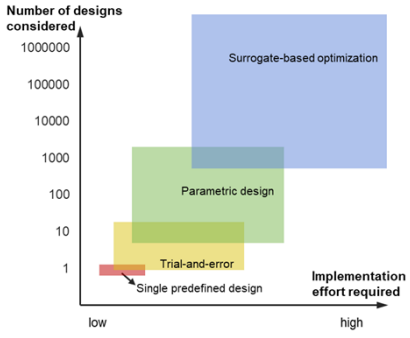
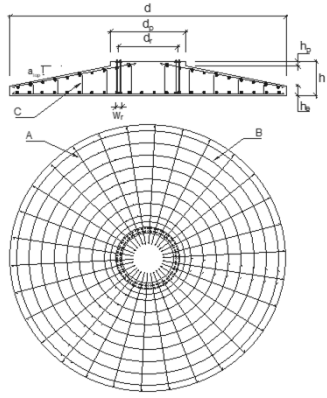
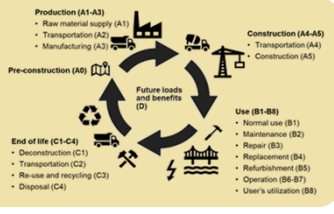




Sustainability assessment

Dimensions
Economic
Environmental
Social
Buildability



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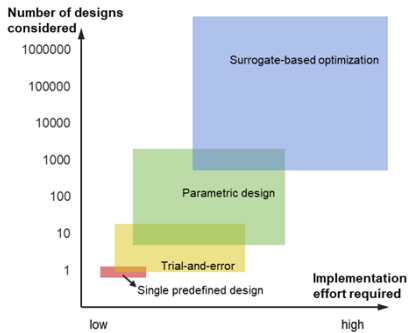

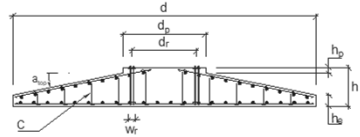

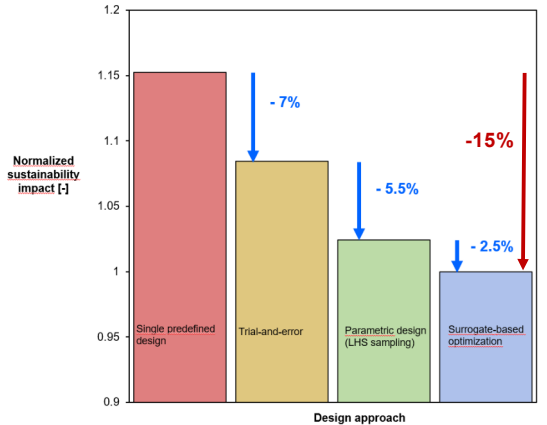

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Quality and service-life of wind turbine foundations

- Interviews with professionals in the Swedish wind power industry
- Case study of a Swedish wind farm

Quality and service-life of wind turbine foundations

Outcomes of the interviews:

Errors and/or defects arising during the construction of foundations usually happen due to poor detailed design or execution

The quality of the concrete surface appears to be a recurring problem, which can cause further problematic degradations during the service life of the foundations.

Inspection of the foundations is often exclusively based on visual assessment of the concrete surface immediately after construction. Quality issues are often poorly documented.

There is a lack of studies on the potential of reusing or extending the service life of foundations and other infrastructures.

Carneiro, E.; Mathern, A.; Olsson, N. Potential improvements in the life-cycle performance of support structures for onshore wind turbines – an interview study in Sweden. Proceedings of XXIV NCR Symposium, Stockholm, June 16-19, **2022**.

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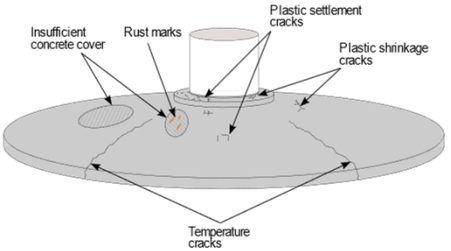
Production and life cycle perfomance



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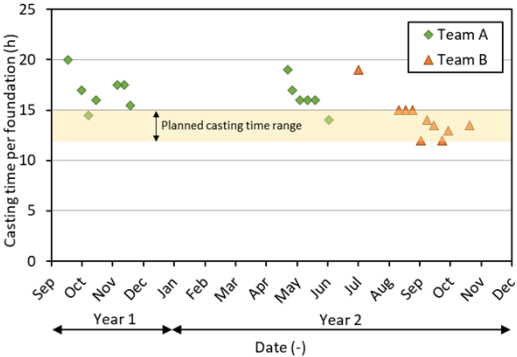
Production and life cycle performance



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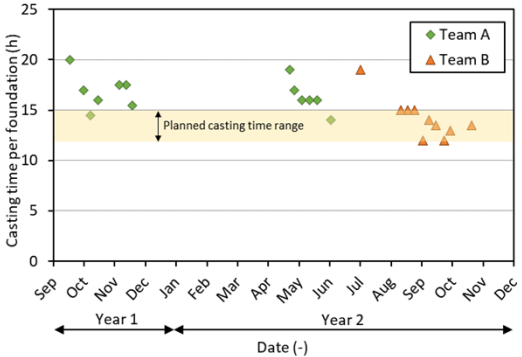

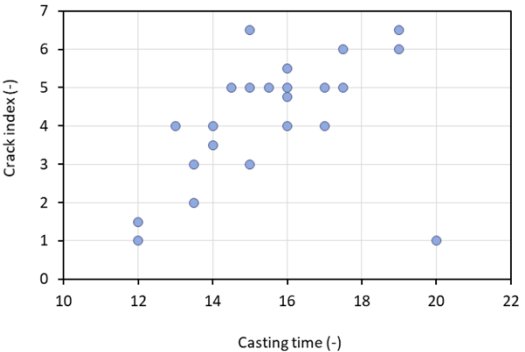

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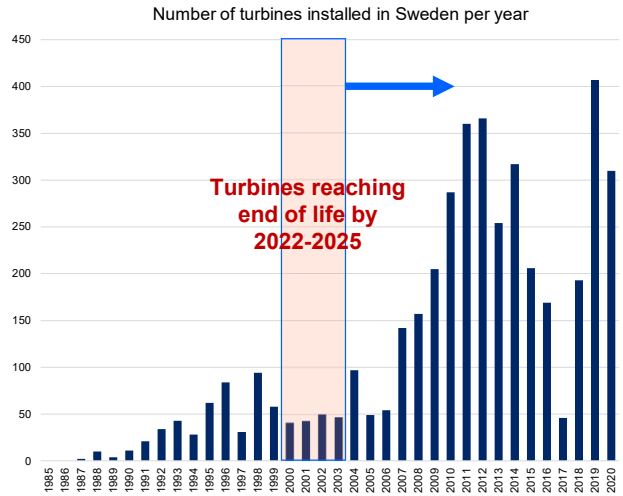
Outlook

How can we design more sustainable foundations?

- **Early multidisciplinary collaboration**
- **Parametric design and optimization**
- **Data-informed decision-making**
- **Good structural and material options**
- **Measure and follow-up**

Outlook

Will reuse/service life extension of foundations become more important in the future?



Publications

Armesto Barros, J.; Mathern, A. Recent and future trends of onshore wind turbine foundations. Proceedings of the IABSE Symposium Prague 2022-Challenges for Existing and Oncoming Structures, International Association for Bridge and Structural Engineering, Prague, Czech Republic, May 25-27, **2022**.

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Concluding remarks

Wind turbine foundations are massive structures whose construction represents a significant sustainability impact.

The parametric design tool applied in this project has the potential to reach more efficient foundation designs.

There is a need to improve data collection and management during construction and inspection of foundations.

Alternative options for end-of-life of foundations need to be researched.