PO.ID 069

Pile-driving analyses of monopiles with pre-fitted flanges

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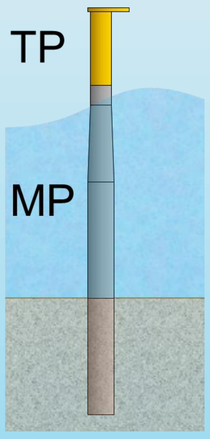
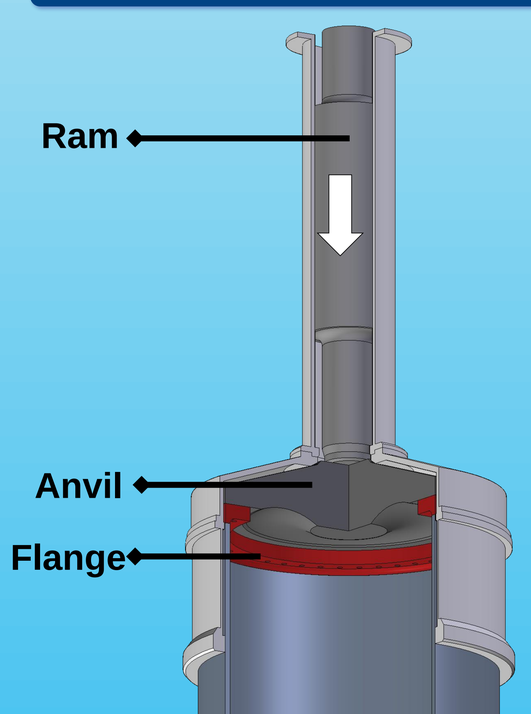
Introduction

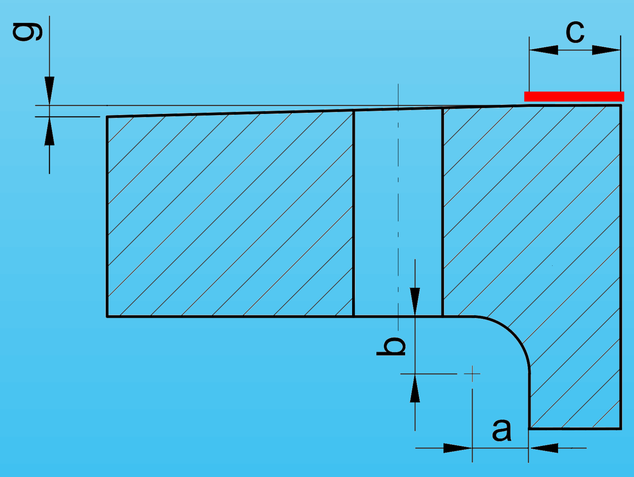


Efforts are being made in the offshore wind energy industry to avoid the highly sophisticated grouted connection between the monopile substructure and transition piece by using a steel-to-steel connection with bolted flanges. This implies that the pile-driving operation by means of a hydraulic hammer is directly performed on the flange surface. The bolted connection would reduce construction and installation costs, but risks concerning damages at the flange structure may occur.
To predict damages induced during driving, comprehensive finite element (FE) analyses are performed under consideration of the essential pile-driving loads.

Pile-driving on Flanges

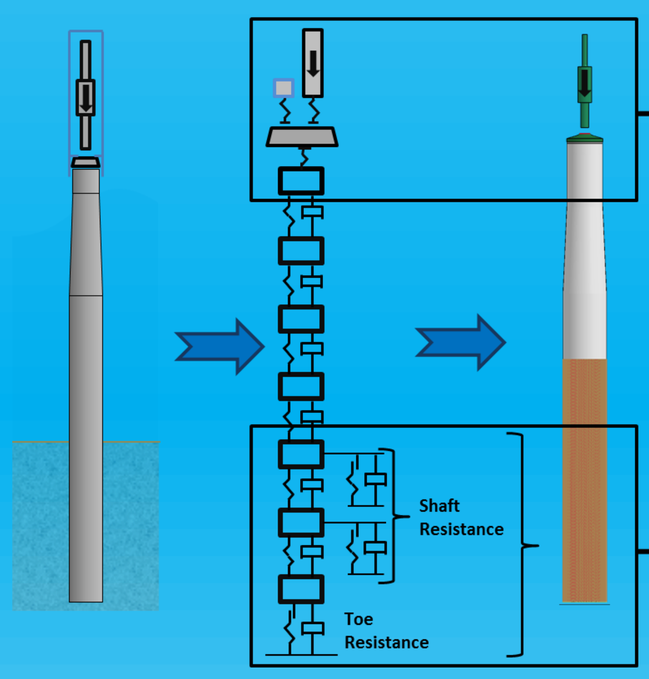


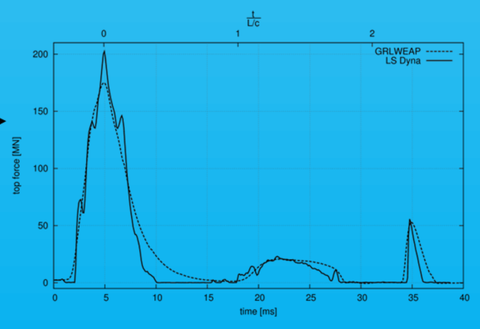
The typical characteristic of flanges designed to withstand pile-driving loads is an inclination of the flange towards the inside. The gap g ensures that the loads act only on the horizontal contact area c.



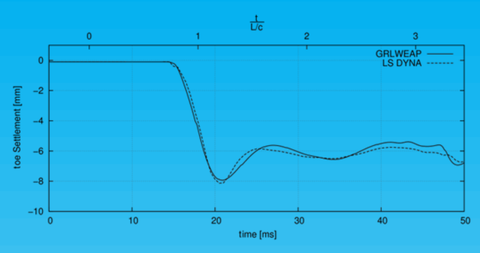
Transfer: Wave-Equation-Analysis to FEM

WEA GRLWEAP — **FEM** LS-DYNA





Validation of FE-results against Wave-Equation-Analysis

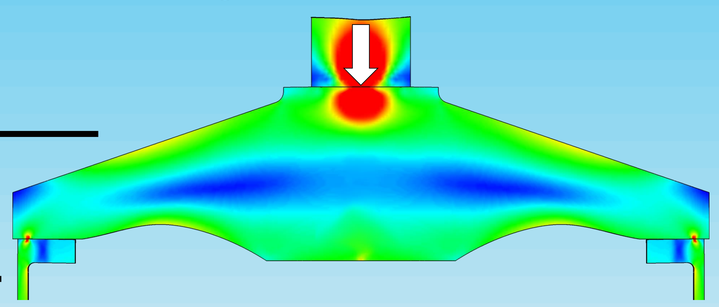


Wave-Equation-Analysis (WEA) in GRLWEAP

- Driveability study: Prediction of blowcount (required number of hammer blows)

Detailed Finite-Element-Analysis in LS-DYNA

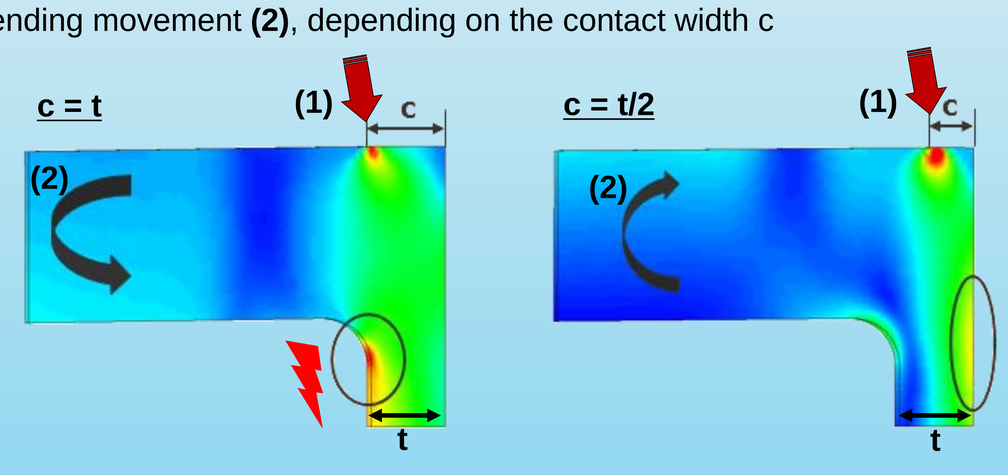
- Dynamic calculation of a single hammer blow
- Simulation of pile-soil interaction by a system of springs and dampers
- Calculation of local stresses at the flange:



Results

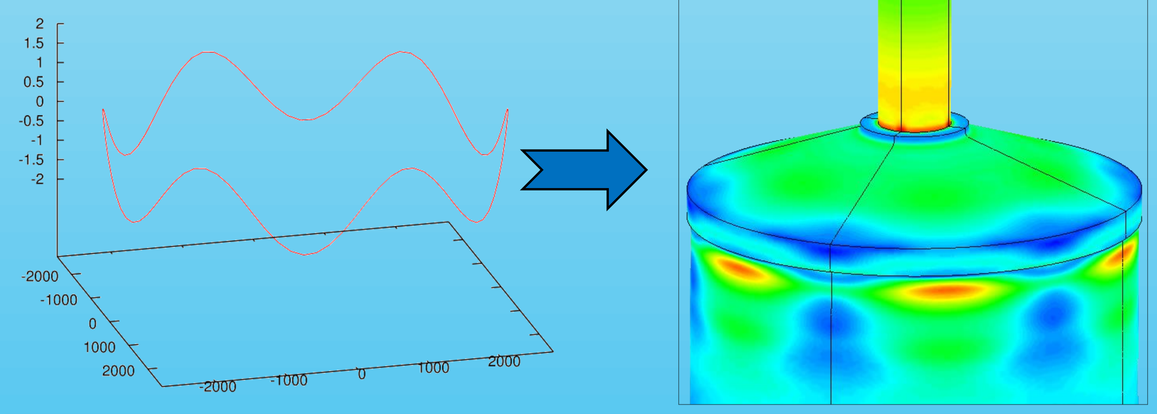
Load transfer between anvil and flange

- Concentrated load **(1)** at the inner edge of the horizontal contact area
- Bending movement **(2)**, depending on the contact width c



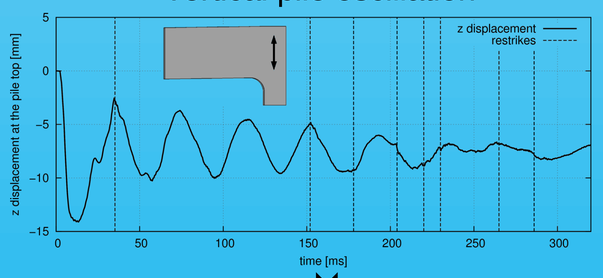
- Optimization of c: Stresses of same magnitude at the inner/outer flange web

Modelling of flatness tolerances

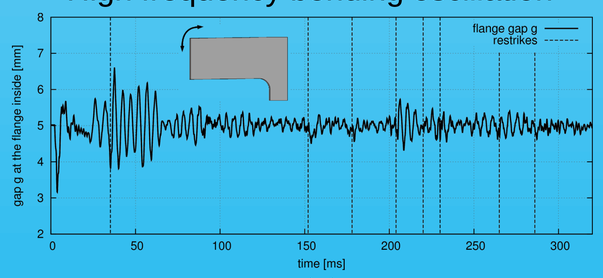


Fatigue evaluation of a single hammer strike

Vertical pile oscillation



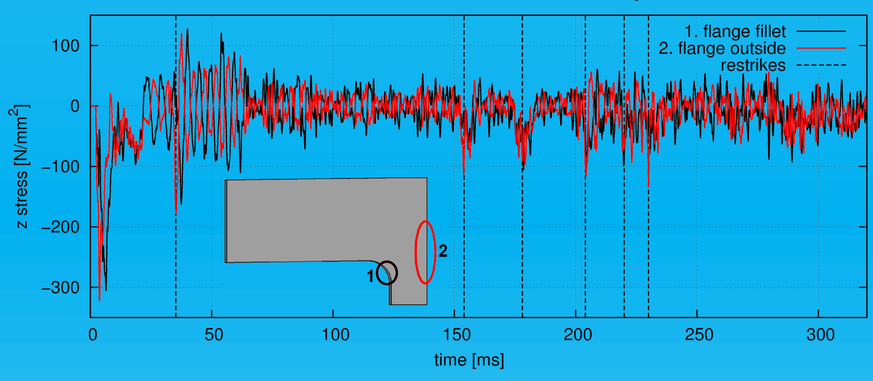
High frequency bending oscillation



Restrikes between the rebounding pile and hammer system

Alternate loading of the flange

Stress-time curve at ‘hot-spots’



- Cumulated fatigue damage $D = \sum D_i * (number\ of\ hammer\ blows)$

Conclusions

The simple, but acknowledged GRLWEAP soil and hammer model was successfully transferred to a detailed finite element model in LS-DYNA, allowing for comprehensive investigations of pile-driving operations.
Small deviations in the flange design as well as manufacturing tolerances may have a huge impact on the load distribution. The fatigue strength of the flange may be critically reduced during driving. In order to design the flange on a safer side, not only the initial hammer strike, but also the subsequent flange oscillation should be considered.

References

1. *DNV-RP-C208,* Determination of Structural Capacity by Non-linear FE Analysis Methods
2. GRLWEAP, *Pile Dynamics Inc.*
3. LS-DYNA, *Dynamore GmbH*

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