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Master on Numerical
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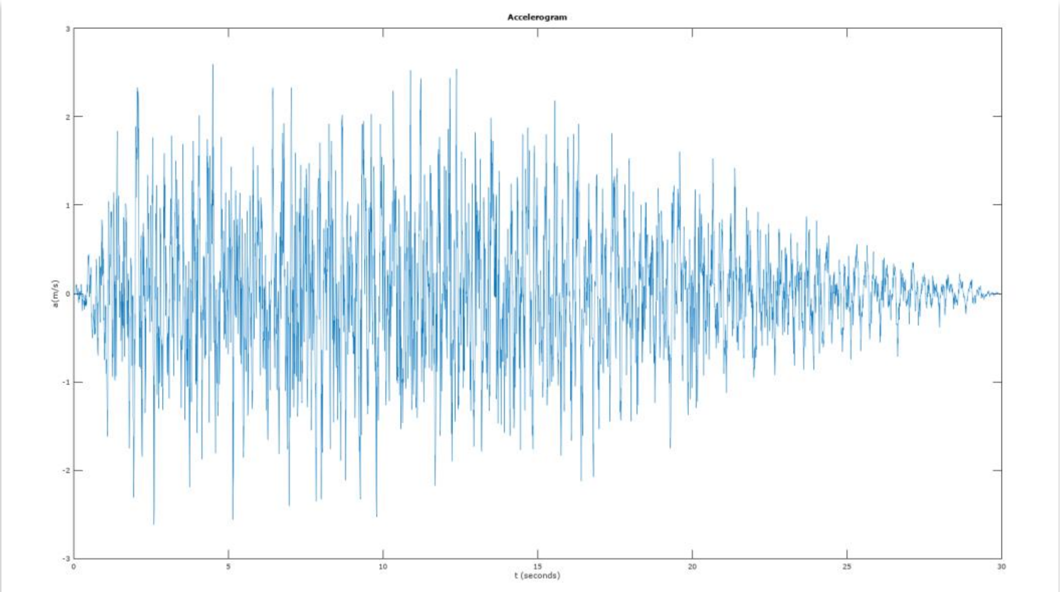
OFFICIAL MASTER of UPC Barcelona Tech



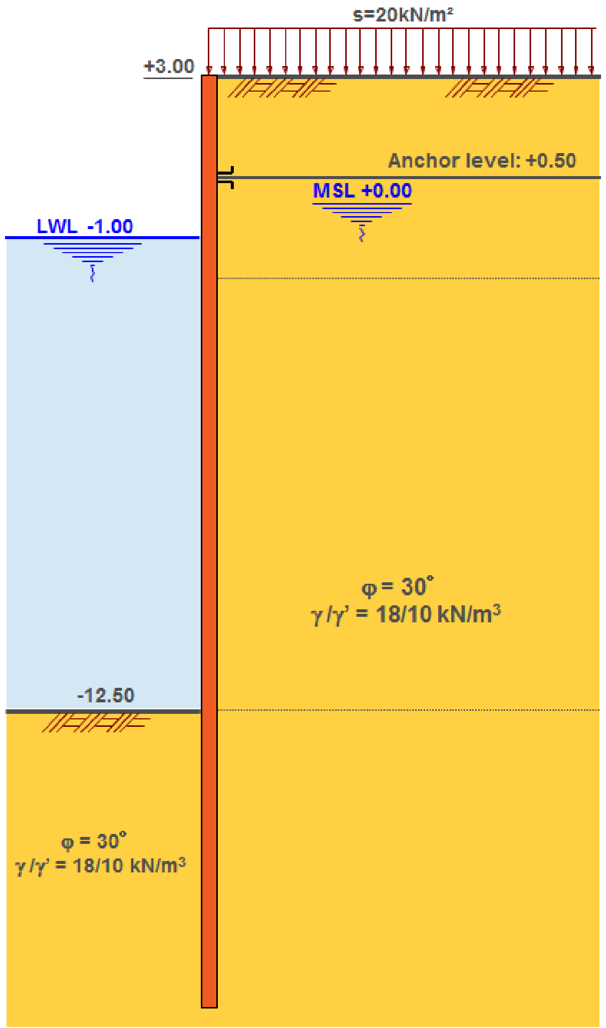

January 2019

# Seismic Design with Steel Sheet Piles

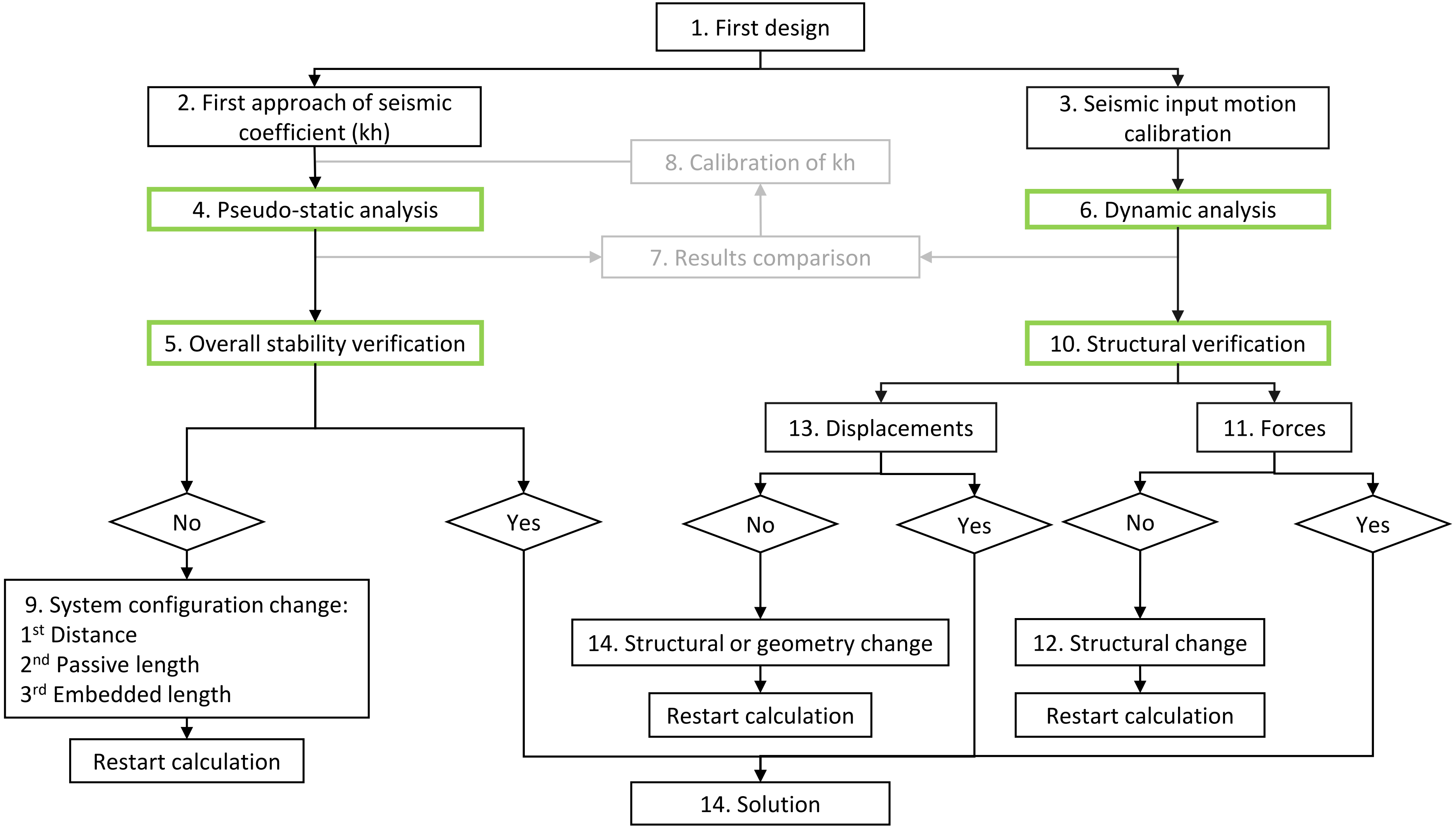
# Index

# Background of the study

- Seismic design study with steel sheet piles proposed by ArcelorMittal in order to:
  - Study their feasibility
  - Stablish a design methodology
- According to Eurocodes and PIANC recommendations
- Calculation by means of 2D Plaxis
- Simple cases changing some design factors



# Basis of design



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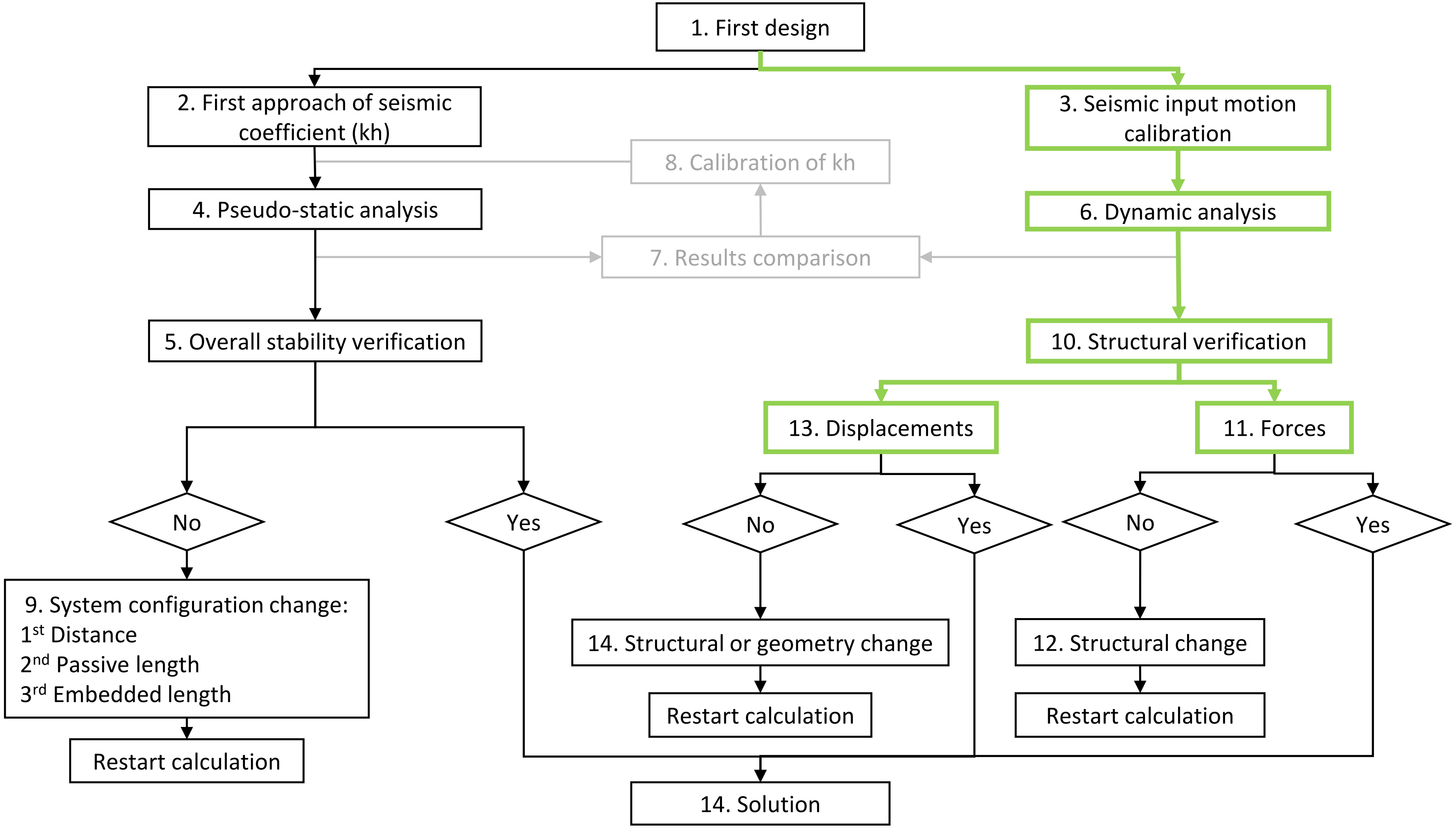
# Dynamic analysis



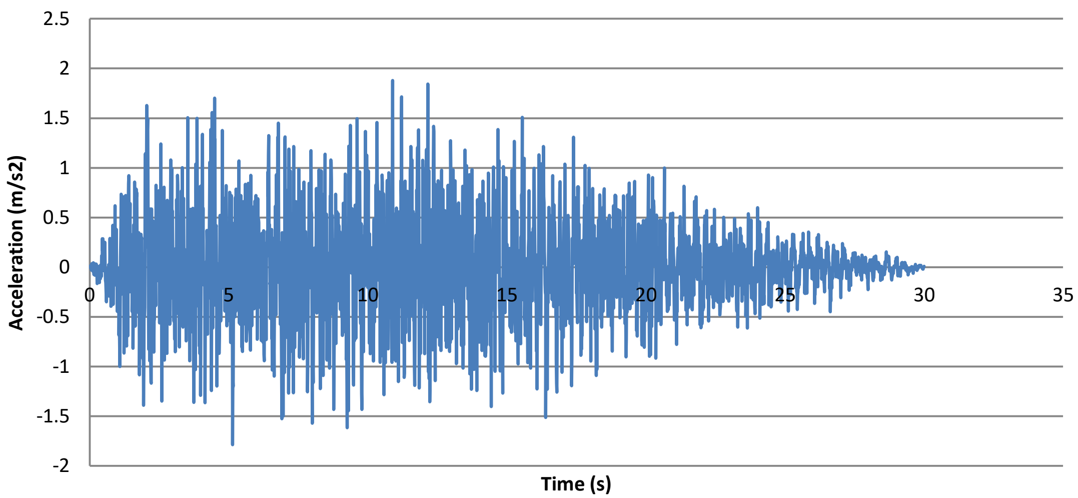
# Dynamic analysis

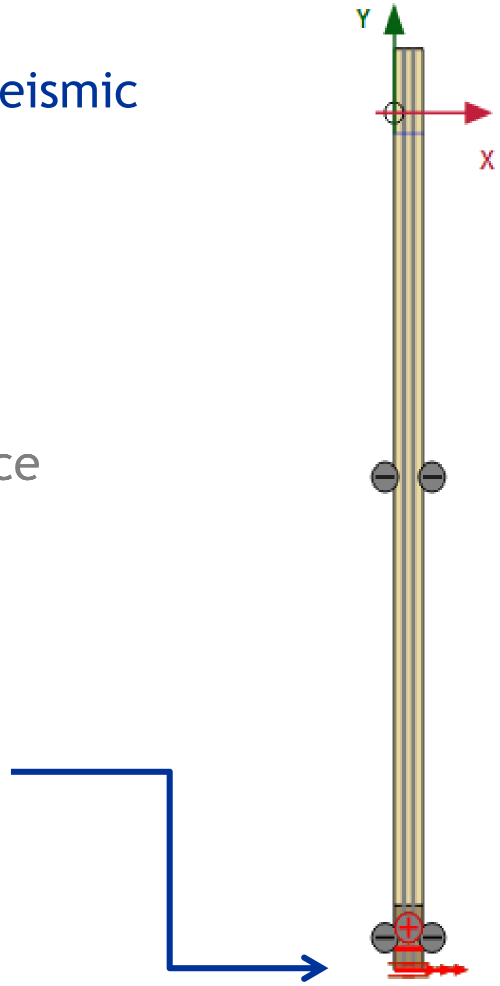
## Seismic input motion calibration

Objective: Obtaining the input seismic signal which gives us the design seismic spectrum at surface.

- 1D model of the soil column is modelled in 2D Plaxis
- The Earthquake is introduced in the model through an accelerogram
- The earthquake is propagated through the soil column until the surface

1st Iteration: Accelerogram associated to rock spectrum



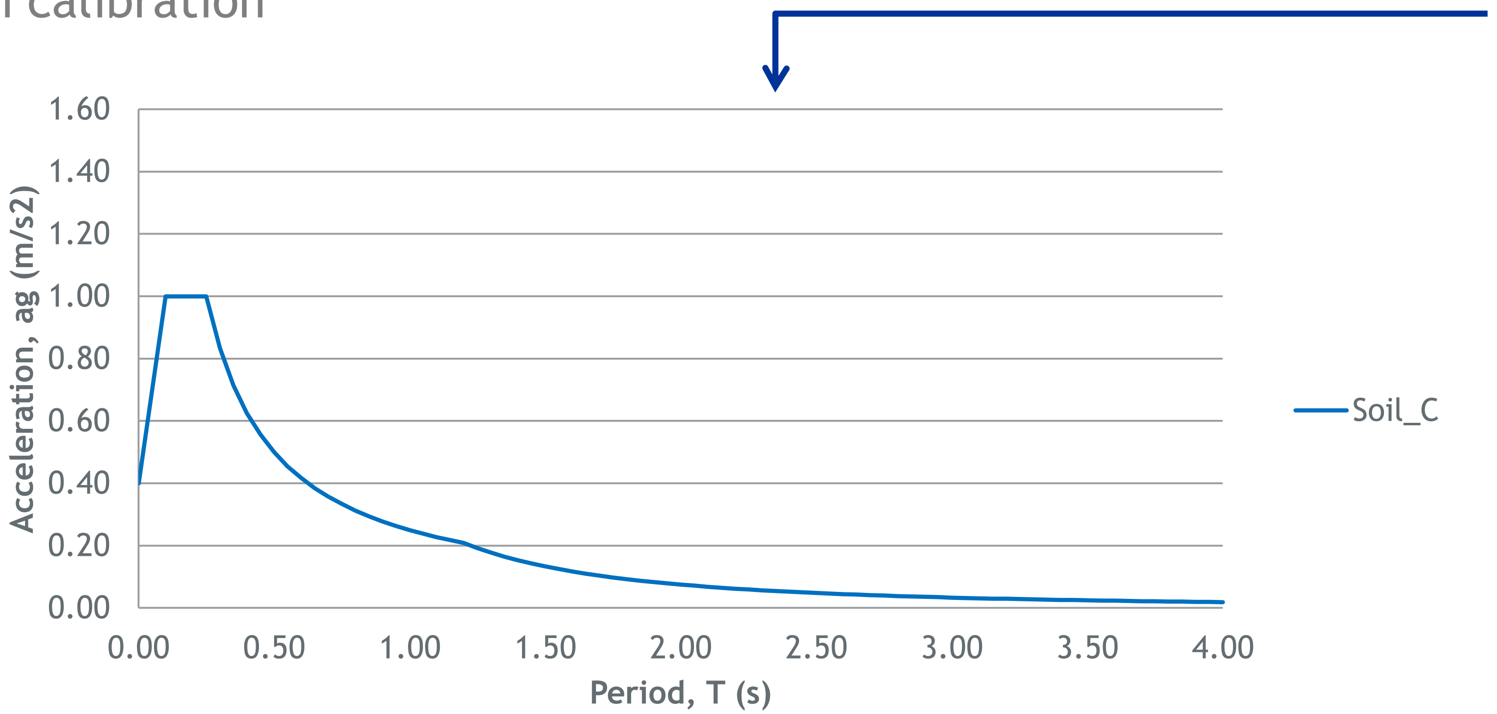



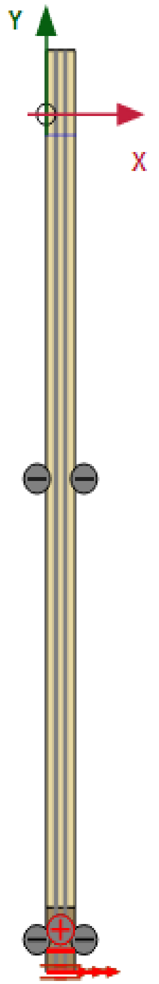
# Dynamic analysis

## Seismic input motion calibration

Target spectrum

- Soil Type C
- PGA=0,4g



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# Dynamic analysis

## Seismic input motion calibration

Target spectrum

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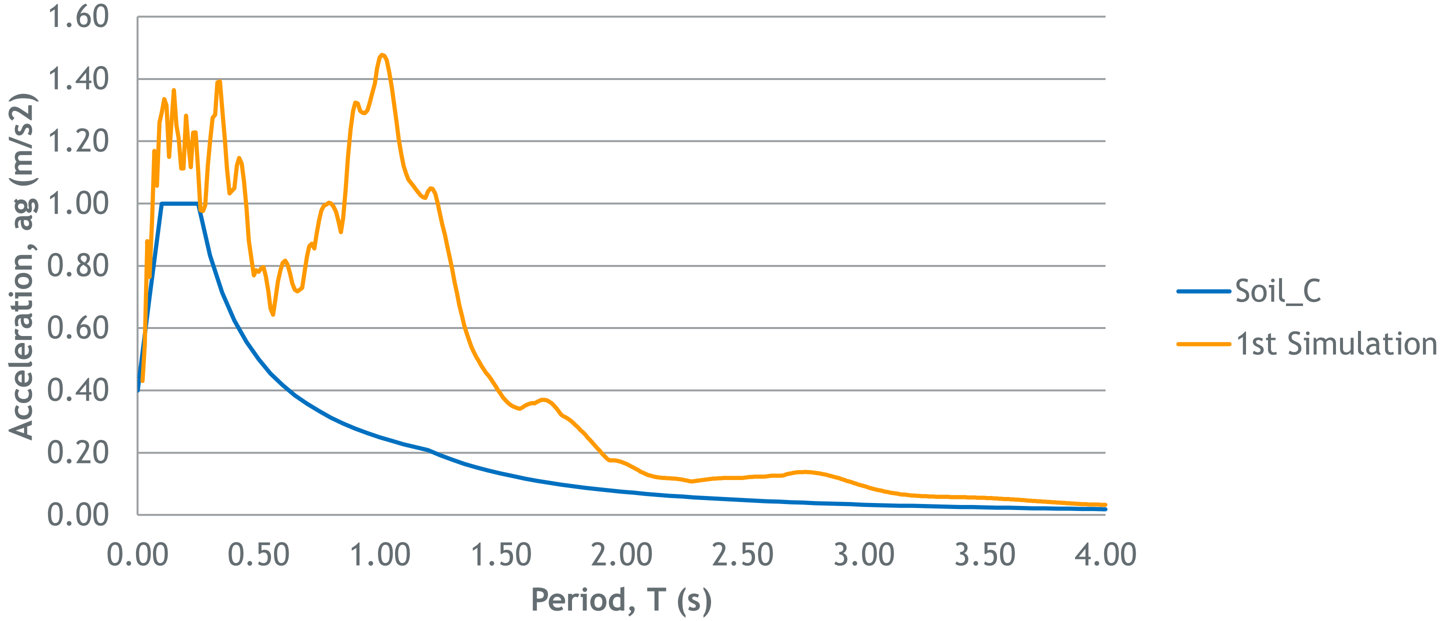
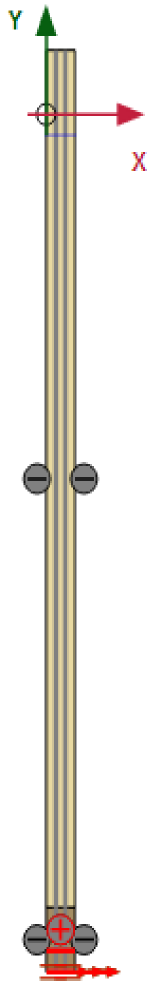


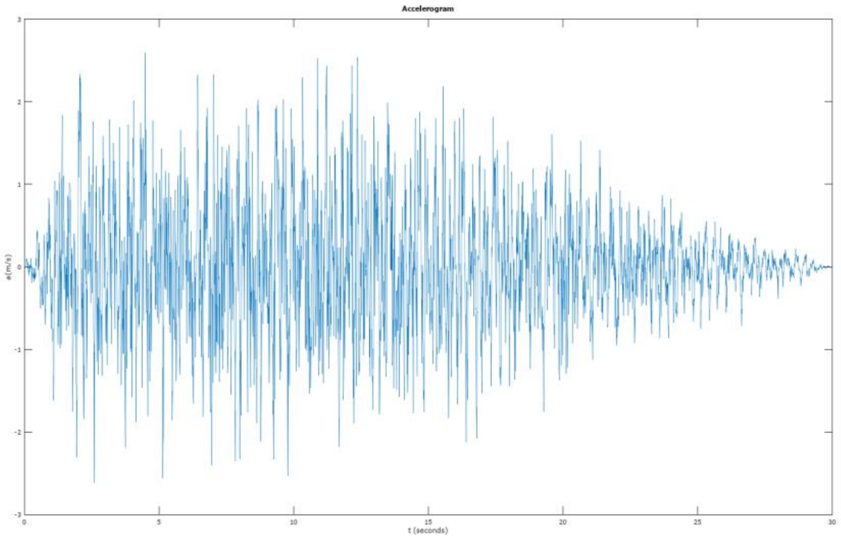

Calibration of the spectrum:

- Rayleigh damping → Soil model
- Fourier Transform → Input signal modification

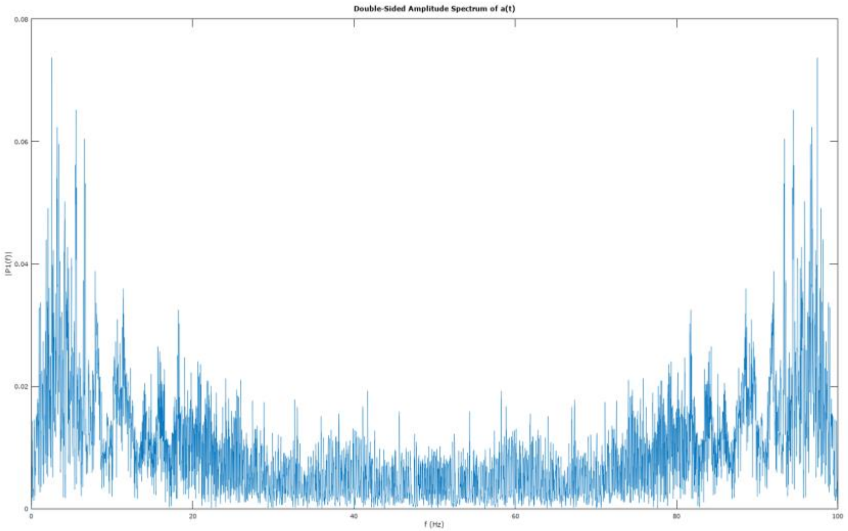
# Dynamic analysis

## Seismic input motion calibration: Fast Fourier Transform

### Fourier Transform of the input accelerogram




### Obtaining of Power Spectral Density



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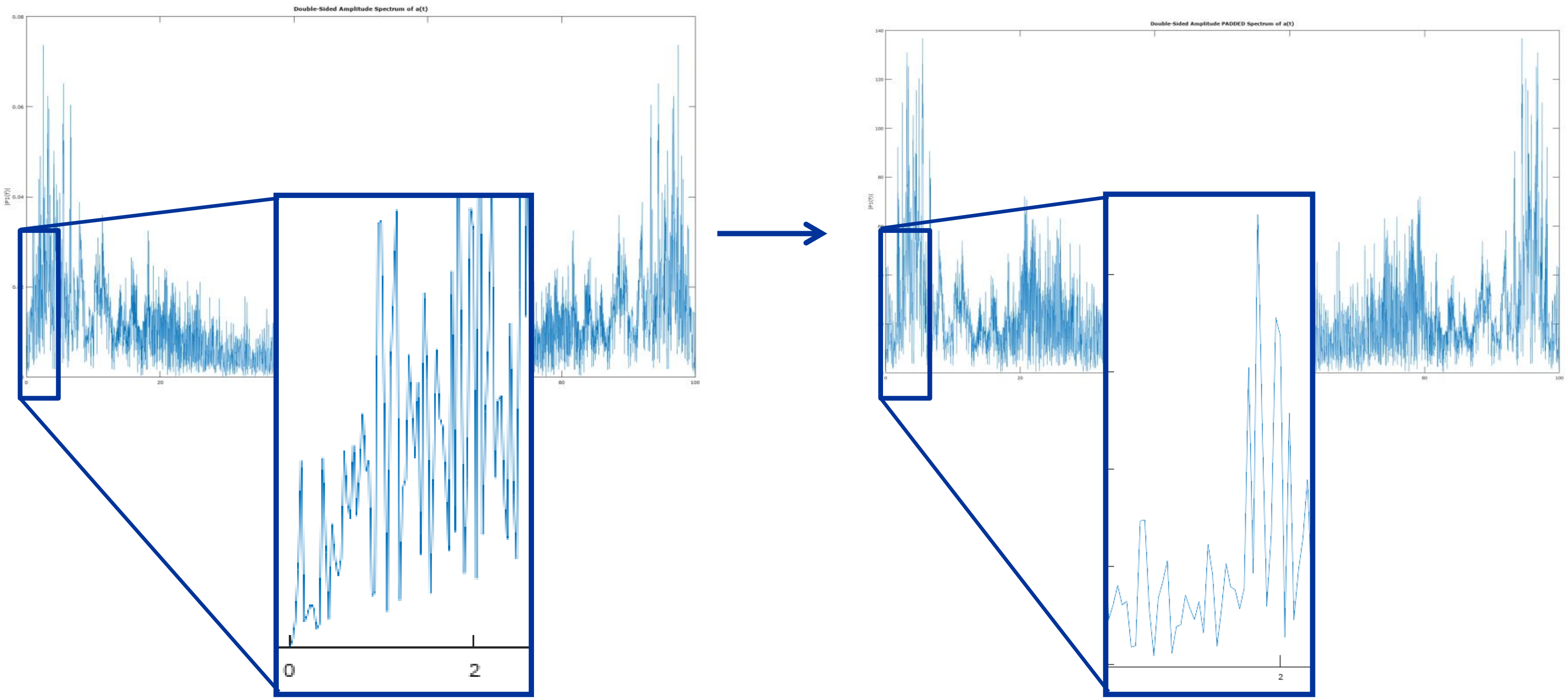
# Dynamic analysis

## Seismic input motion calibration: Fast Fourier Transform

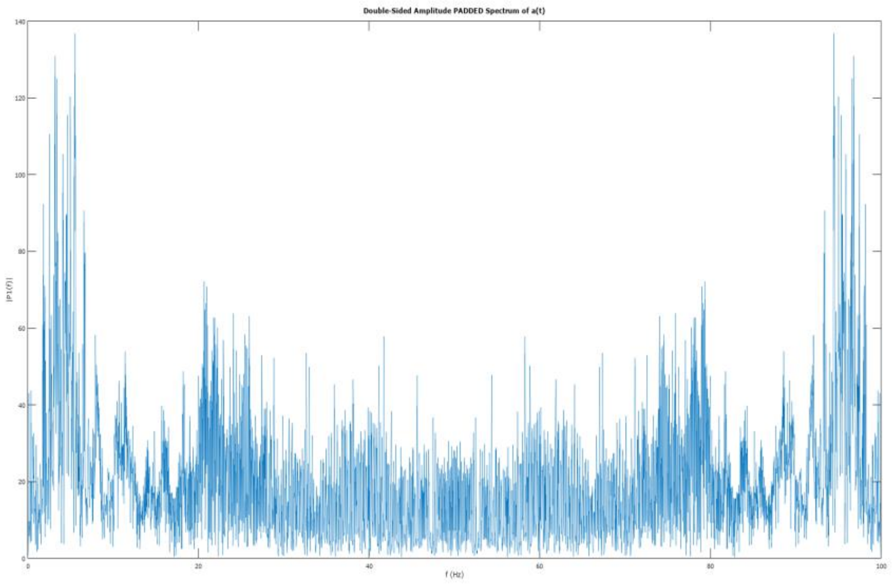
### Modification of the energy of frequencies under interest



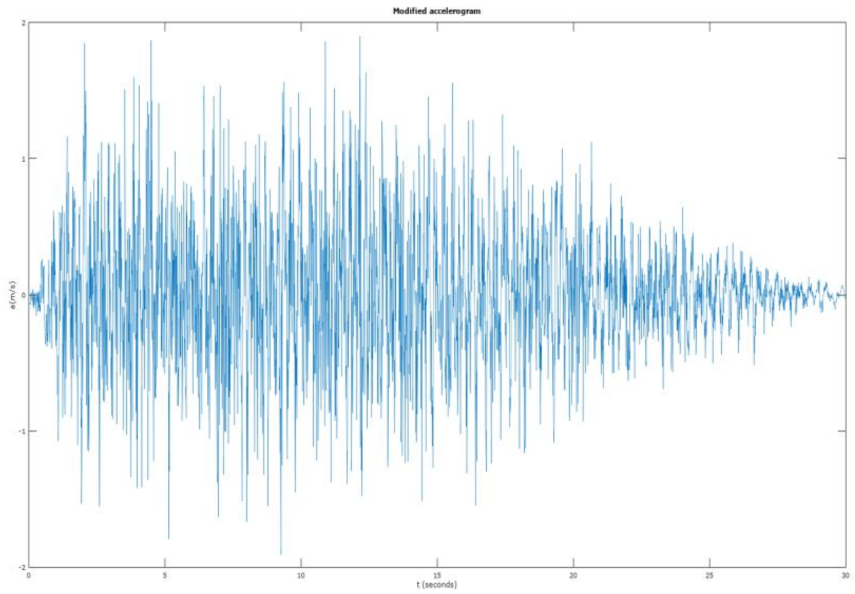
# Dynamic analysis

## Seismic input motion calibration: Fast Fourier Transform

Inverted Fourier Transform




Obtaining the modified accelerogram

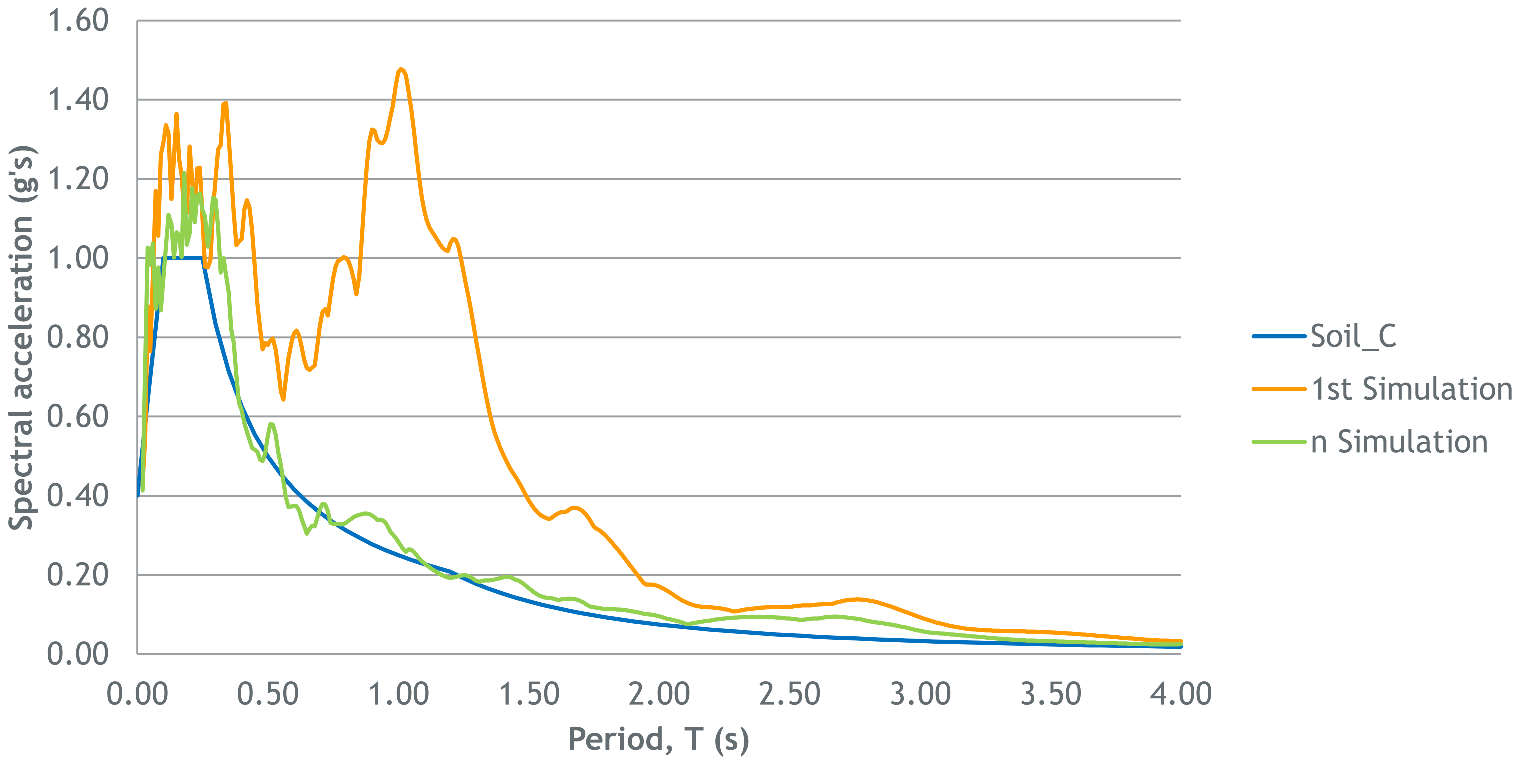


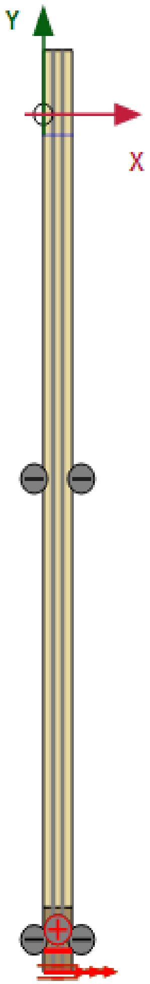
# Dynamic analysis

## Seismic input motion calibration: Fast Fourier Transform

Target spectrum

- Soil Type C
- PGA=0,4g





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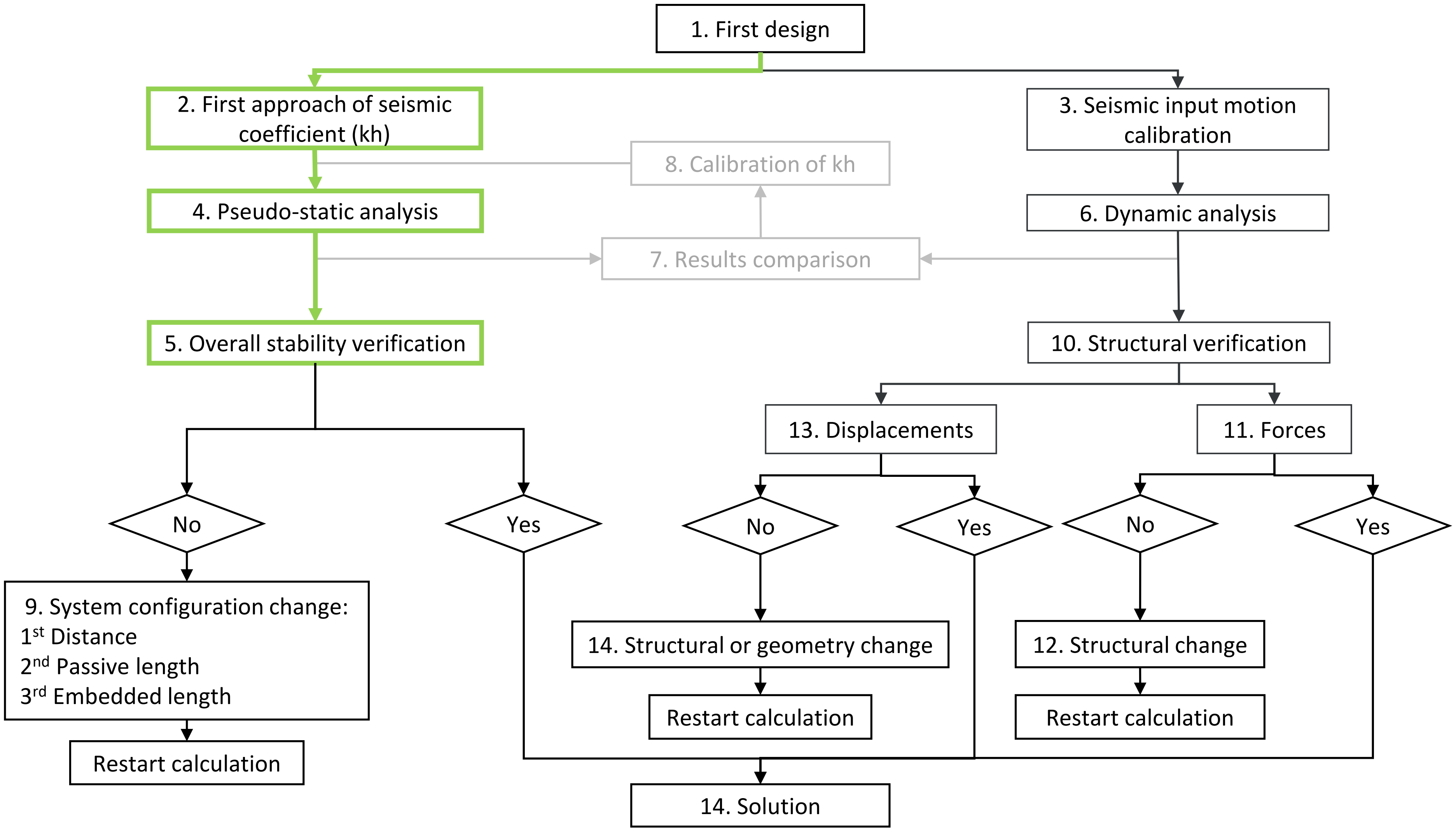
# Pseudo-static analysis



# Pseudo-static analysis

## Estimation of the seismic coefficient

The earthquake is introduced as an additional inertial force by means of the seismic coefficient ($k_h$)

$$k_h = \alpha \frac{S}{r}$$

# Pseudo-static analysis

## Estimation of the seismic coefficient

The earthquake is introduced as an additional inertial force by means of the seismic coefficient ($k_h$)

$$k_h = \alpha \frac{S}{r}$$

Reduction factor

**Table 7.1 — Values of factor *r* for the calculation of the horizontal seismic coefficient**

| Type of retaining structure | $r$ |
|---|---|
| Free gravity walls that can accept a displacement up to $d_r = 300\ \alpha \cdot S$ (mm) | 2 |
| Free gravity walls that can accept a displacement up to $d_r = 200\ \alpha \cdot S$ (mm) | 1,5 |
| Flexural reinforced concrete walls, anchored or braced walls, reinforced concrete walls founded on vertical piles, restrained basement walls and bridge abutments | 1 |

ArcelorMittal's proposal: r=1.67 (1/0.6) according to PIANC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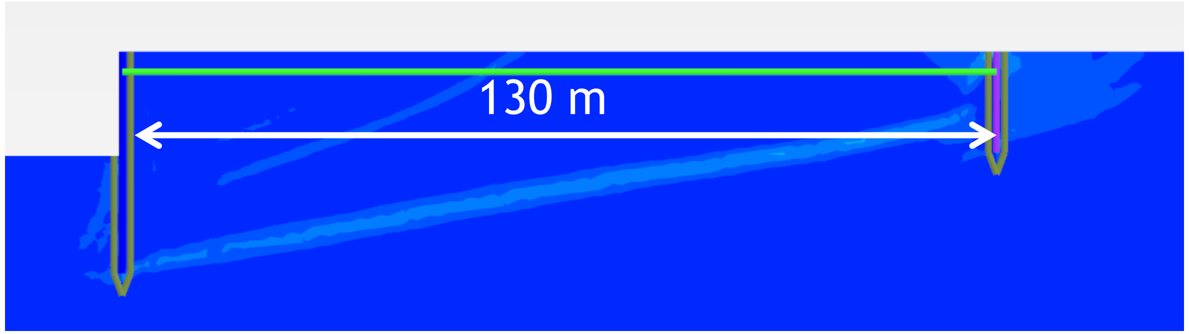
# Pseudo-static analysis

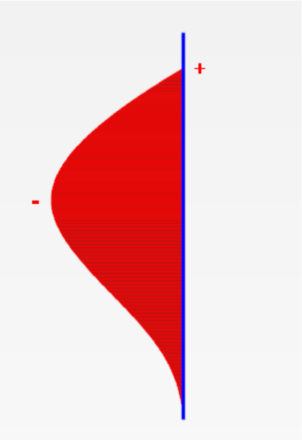
## Results with r=1.67 ($k_h$=0.24)




Passive wall distance too high for r=1.67

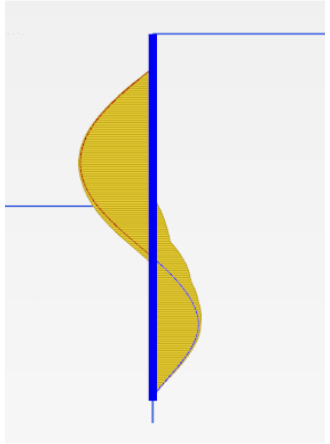
### Results comparison: Bending moment distribution

(Pseudo-static)




Mmax=6723 kNm

≠

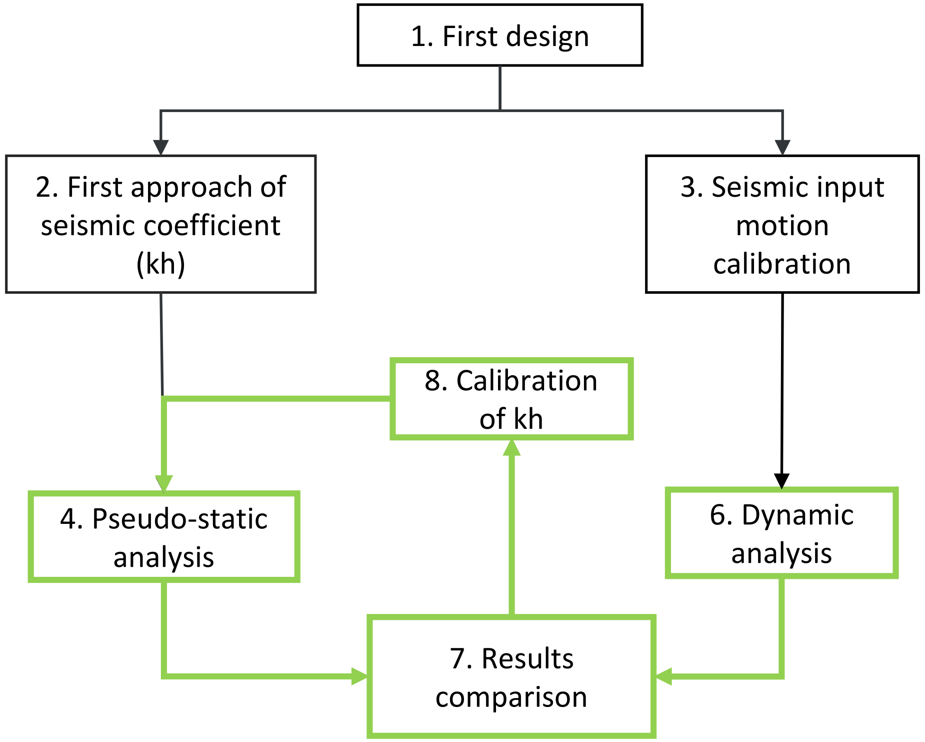


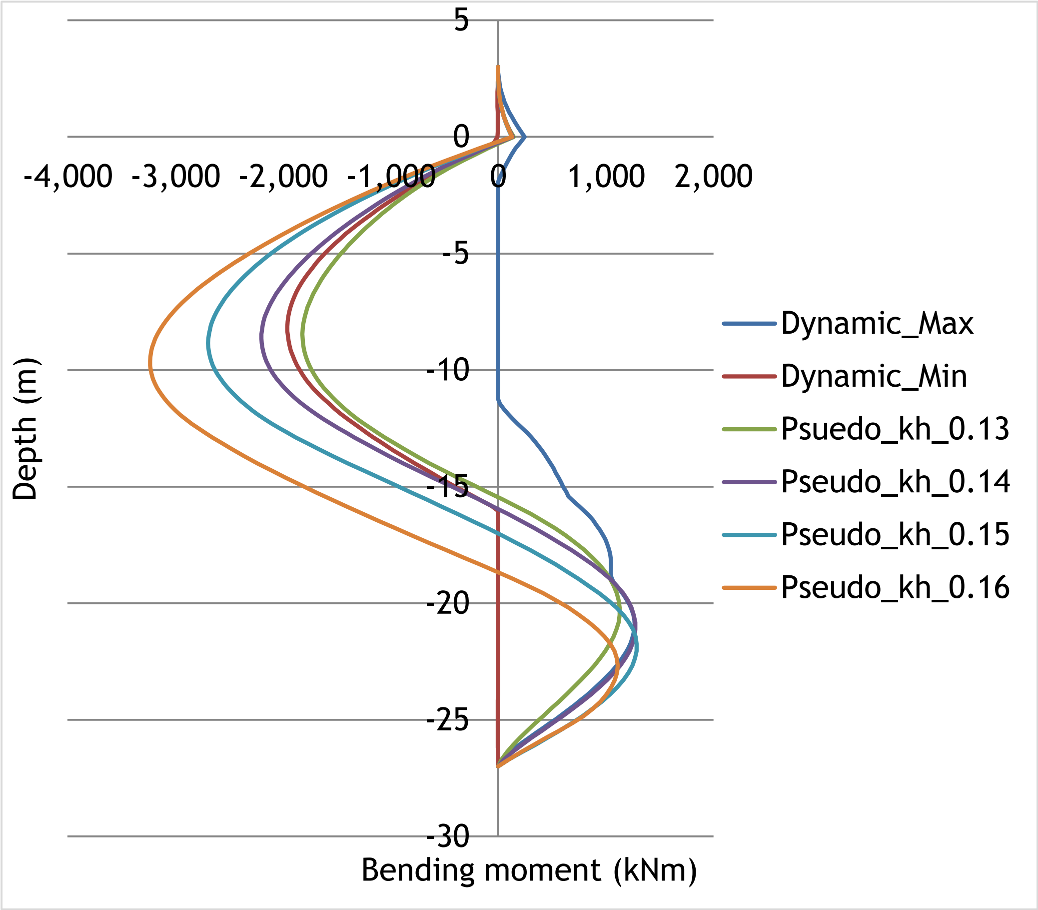
(Dynamic)

Mmax=2835 kNm

# Pseudo-static analysis

## Estimation of the seismic coefficient




Design seismic coefficient:

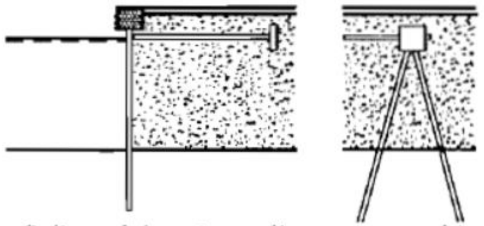
- kh=0,14g ⟶ r=2,8

# Results

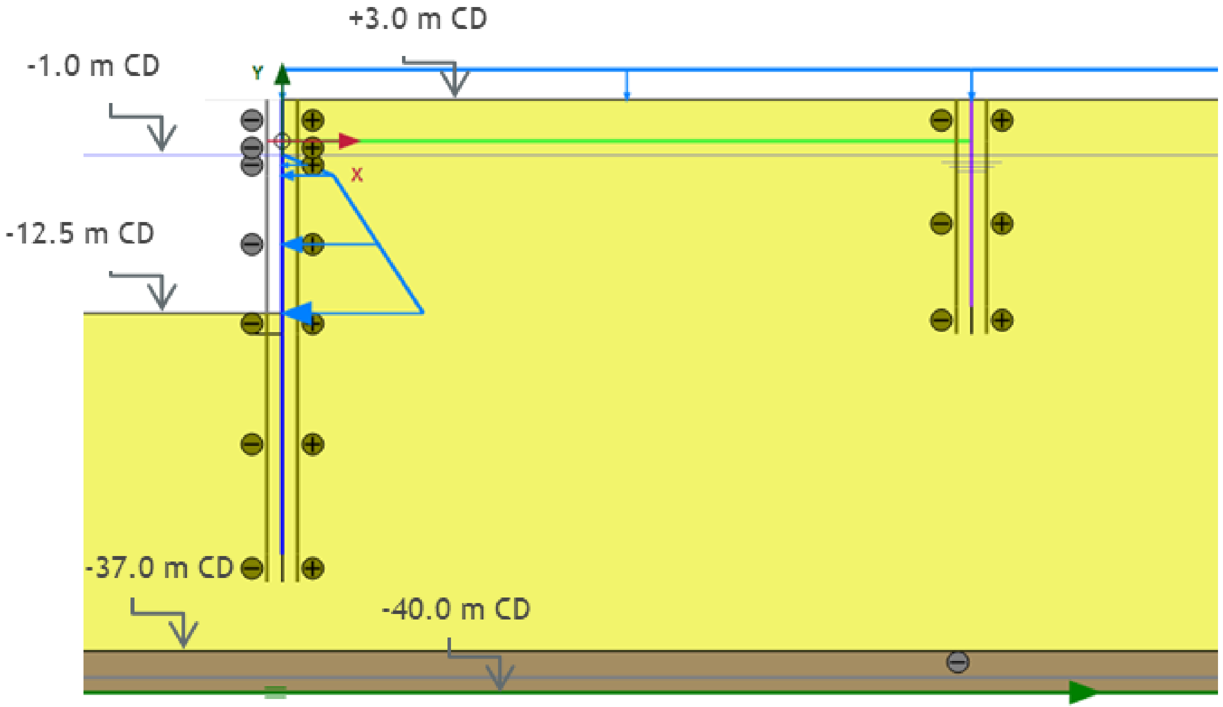
## Cases of the study

| Case of study | System | Sea bed level |
|---|---|---|
| C_SS(10.50) | Passive wall | -10.50 |
| C_SS(12.50) | Passive wall | -12.50 |
| C_SS(14.50) | Passive wall | -14.50 |
| C_SP(10.50) | Batter pile system | -10.50 |
| C_SP(12.50) | Batter pile system | -12.50 |
| C_SP(14.50) | Batter pile system | -14.50 |

Sheet pile



•Soil retaining sheet pile structure with auxiliary structures for anchoring.
•Sheet pile, fill-soil foundation.



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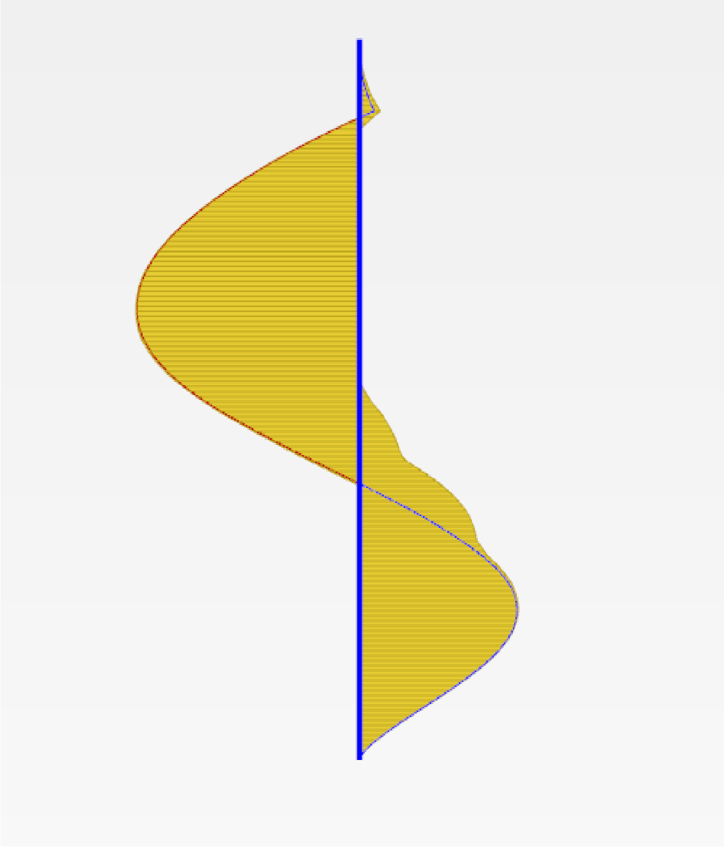
# Results

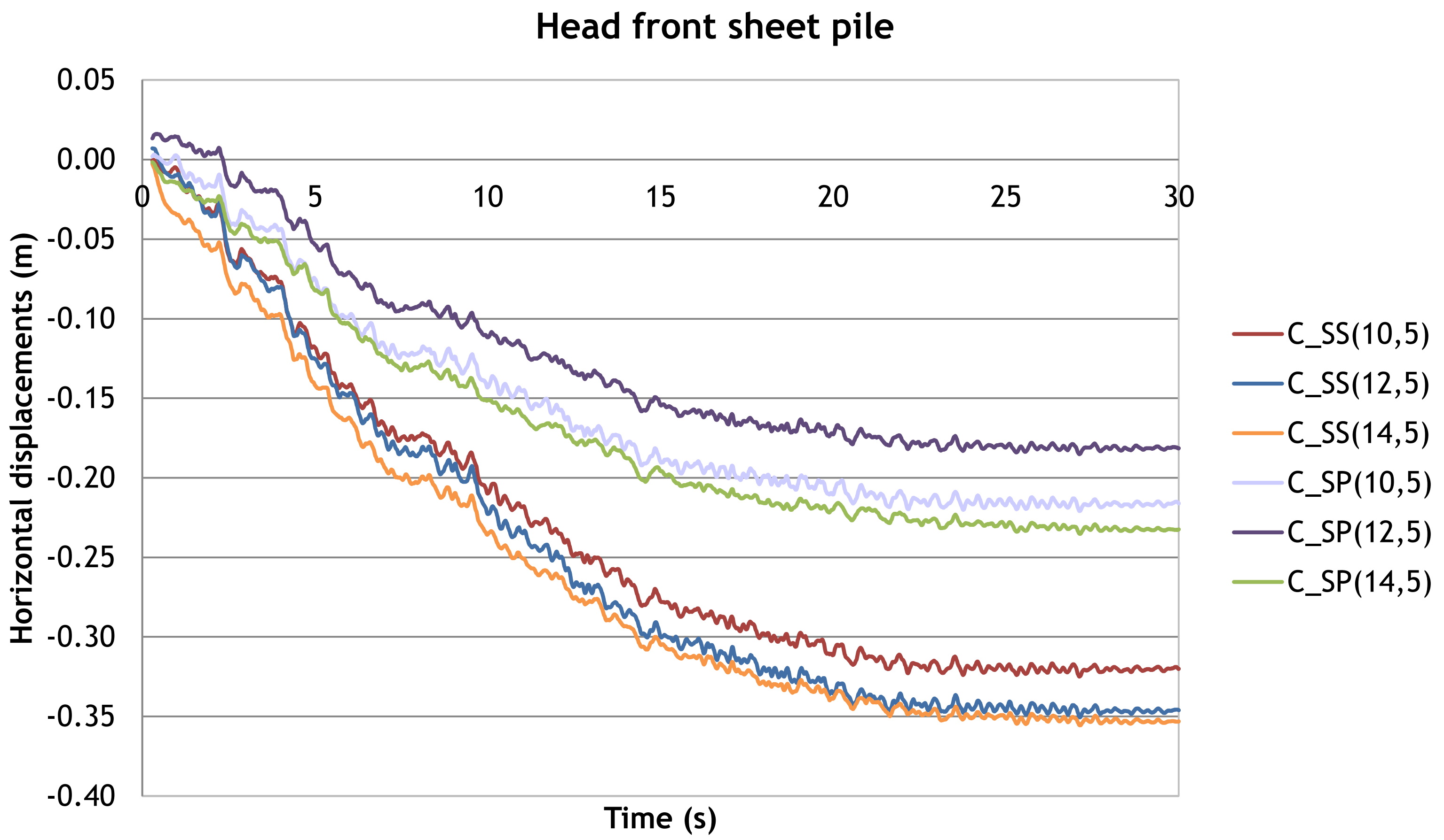
## Dynamic analysis: Bending moment distribution

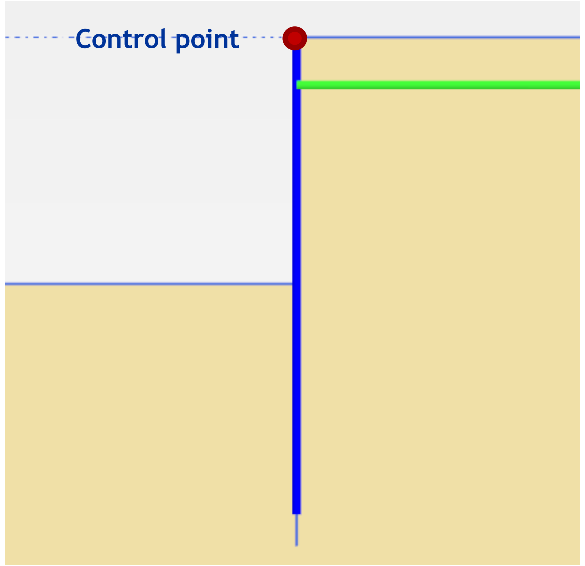


| Case | Maximum positive bending moment (kNm/m) | Maximum negative bending moment (kNm/m) |
|---|---|---|
| C_SS(10.50) | 976 | 1398 |
| C_SS(12.50) | 2151 | 2131 |
| C_SS(14.50) | 2471 | 3672 |
| C_SP(10.50) | 913 | 1419 |
| C_SP(12.50) | 1388 | 2198 |
| C_SP(14.50) | 2190 | 3595 |

# Results

## Dynamic analysis: Displacements

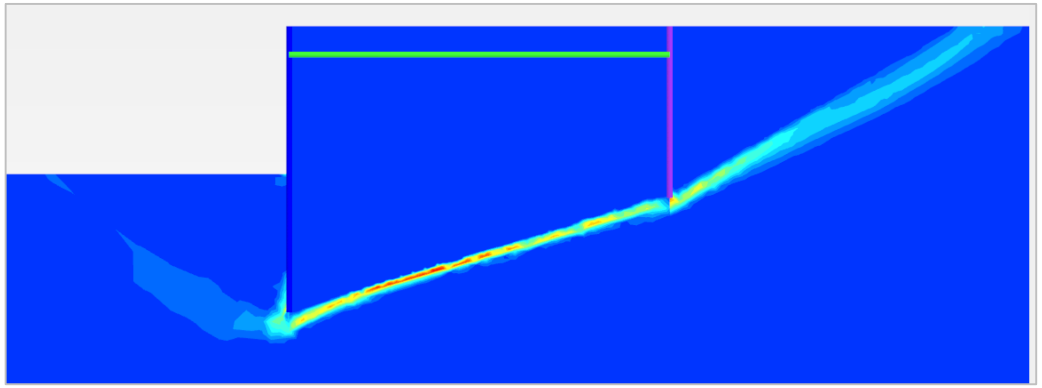



Stability on permanent displacements

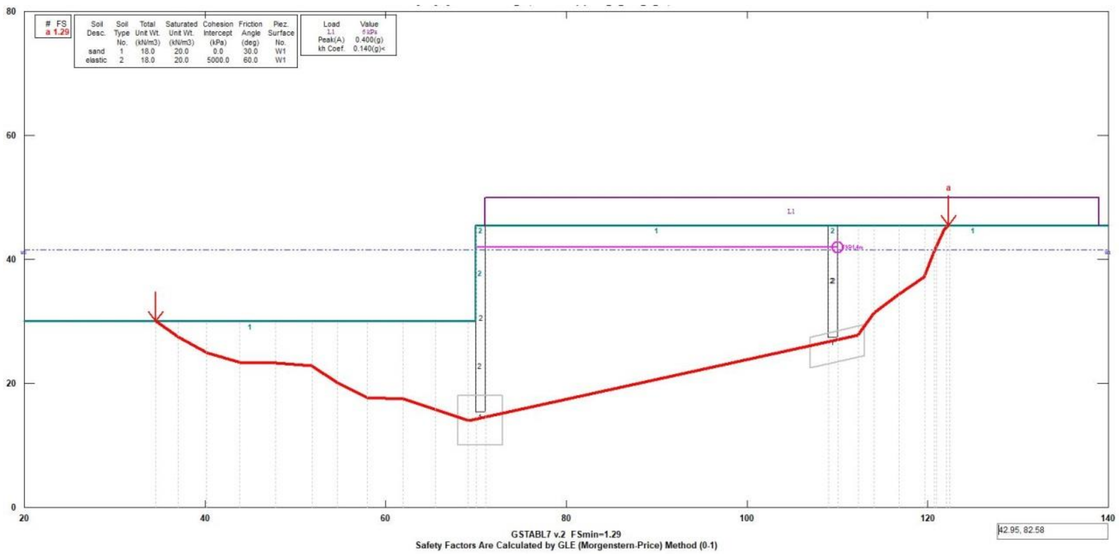
# Results

## Pseudo-static analysis: Overall stability of the system (40 m tieback)



2D Plaxis (FEM)
FS=1,27

GSTABL (LEM)
FS=1,29



# Conclusions

- The reduction factor might range between 2.5-3.
  - Overseas Coastal Area Development Institute of Japan proposes reductions between 50%-30% (factors between 2 and 3).
  - C.J.Habets, et.al (2018), " Model solutions for performance-based seismic analysis of an anchored sheet pile quay wall“ defines factors between 1.8-2.
  - In Eurocode 1998-5 the maximum reduction factor is 2 and applicable to gravity walls.
- The reduction factor mainly depends on the ductility of the soil-structure system.

# Further studies

- Different soil configurations need to be studied. In this case a single layer model has been used but at least the following has to be included:
  - Multilayered soils.
  - Cohesive soils.
- The effect of the steel sheet piles stiffness on the results has to be addressed.
- The plasticity on the steel has to be considered, in this case only linear elastic material has been used for the calculations.
- Hydrodynamic water pressures have to be included:
  - Westergaard pressures as static loads (usual approach).
  - Coupled soil-structure-fluid interaction (not available in Plaxis).

# THANK YOU