Synthetic Dataset of Anchored Backfilled Quay Walls for Surrogate Model Development

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This data publication comprises a synthetic databank obtained through numerical simulation of an anchored, backfilled sheet pile quay wall. The simulations were executed using the finite element method (FEM) within the commercial software package PLAXIS 2D in version 2024.3 (Plaxis, 2024) driven via a remote Python scripting interface (Van Rossum et al., 2009). The databank is designed to facilitate foundations for supervised machine learning architectures, such as neural network-based surrogate modelling, for soil–structure interaction problems without requiring computationally intensive continuum calculations.

Boundary value problem

The plane strain finite element model configurations, geometric boundary constraints, and input variables are defined in Figure 1. The quay wall structural behavior is represented via elastoplastic beam elements, while the tie-back anchorage is modeled as a spring support using a fixed-end anchor (FE-anchor) system.

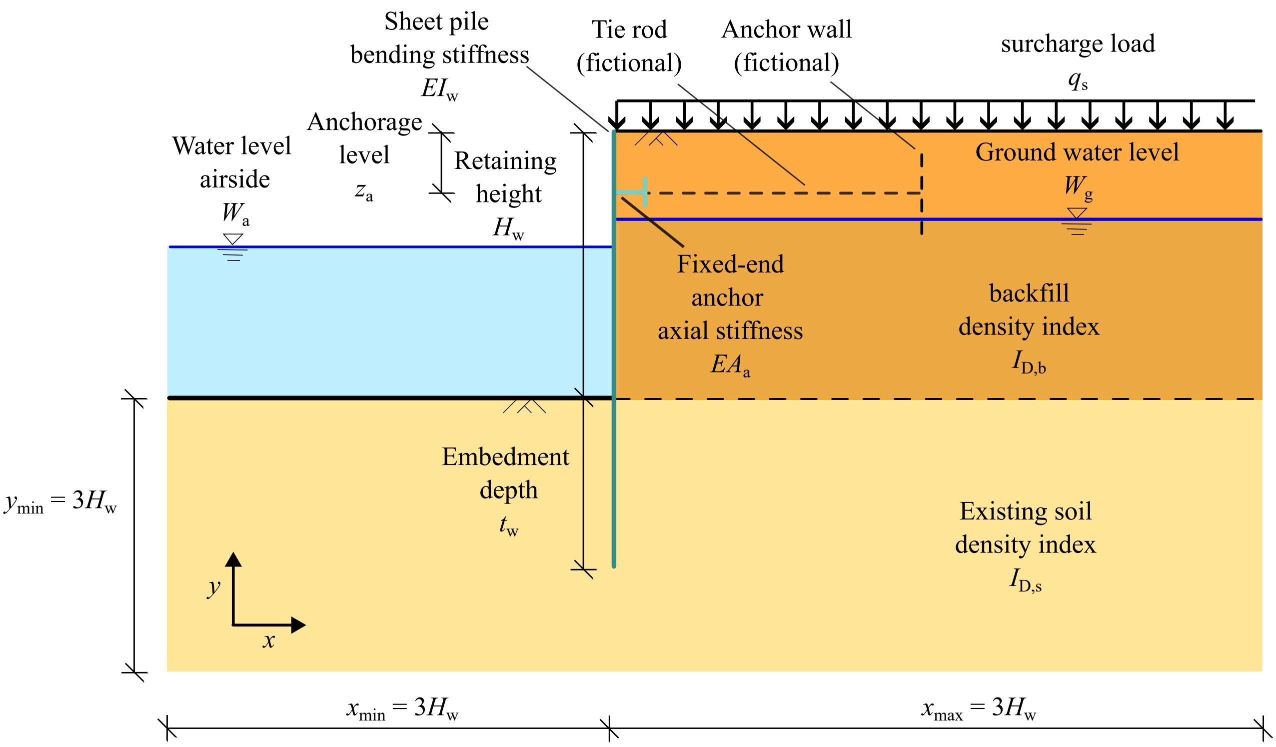

Figure 1: System sketch, boundary conditions, input variables and spatial configuration of the backfilled quay wall model.

The soil–structure interaction of the quay wall is modelled using the Hardening Soil model with small-strain stiffness (HSsmall), an elastoplastic multi-yield surface formulation that extends the standard Hardening Soil model (Schanz, 1998) by incorporating strain-dependent stiffness at very small strain levels (Benz, 2006). The behaviour of coarse-grained soils is parameterised through the density index of

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the existing soil $I_{D,s}$ and the backfill $I_{D,b}$, which provide consistent estimates of the HSsmall constitutive parameters (Brinkgreve et al., 2010). The calculation phases are listed and described in Table 1 and shown in Figure 2.

Table 1: Staged construction calculation phases implemented in the FEM model

Phase	Phase Name	Description
Phase 0	Initial phase	Stress field initialization using the K_0-procedure for horizontally stratified soil with a phreatic surface matched to the initial airside water table W_a.
Phase 1	Installation sheet pile	Activation of the sheet pile plate element with its full stiffness using the "wished-in-place" modelling method.
Phase 2	1st backfill	Activation of the initial backfill soil polygon between the wall and the anchor domain, bounded geometrically by active and passive Rankine failure wedges.
Phase 3	Anchor + 2nd backfill	Activation of the fixed-end anchor connection and the second backfill soil polygon.
Phase 4	Loading	Application of the external uniform surcharge load q_s and hydrostatic water pressure difference (water levels: W_g and W_a).

Sample Space and Parametric Ranges

The multi-dimensional sampling space is generated using latin hypercube sampling (LHS). The number of desired samples was set to 10,000. However, extreme parameter configurations triggering numerical instability and non-convergence inside the FEM solver were filtered out, resulting in a compiled operational databank of 4,159 data entries. Table 2 outlines the ranges defining the sampling boundaries.

Table 2: Input parameter configurations and sampling ranges Range = [lower boundary : step : upper boundary]

Notation	Parameter definition	Variable	Range boundary intervals	Unit
x_1	Retaining height	H_w	[3.0 : 0.5 : 35.0]	m
x_2	Anchorage level[a]	z_a	$[0.5 : 0.1 : \frac{1}{3}H_w]$	m
x_3	Embedment depth ratio	t_w	$[0.1H_w : 0.1 : 1.5H_w]$	m
x_4	Anchor axial stiffness	EA_a	$[3.8 \cdot 10^5 : 2.0 \cdot 10^5 : 27.8 \cdot 10^5]$	kN
x_5	Sheet pile profile stiffness[b]	EI_w	(AZ 12-700 to AZ 52-700)	kNm^2
x_6	Surcharge load	q_s	[10.0 : 5.0 : 50.0]	kN/m^2
x_7	Airside water level[a]	W_a	$[\frac{1}{3}H_w : 0.1 : \frac{2}{3}H_w]$	m
x_8	Groundwater level[a]	W_g	$[W_a - 0.5 : 0.1 : \max(W_a - 5.0, 0.0)]$	m
x_9	Relative density of existing soil	$I_{D,s}$	[15.0% : 1.0% : 85.0%]	%
x_{10}	Relative density of backfill soil	$I_{D,b}$	[15.0% : 1.0% : 85.0%]	%

[a] measured from the top of the wall
[b] Profiles acc. ArcelorMittal Sheet Pilling, 2025

Structure and content of the result file

All converged simulations are saved in a summary file `summary_results_LHS.txt`, which contains index row numbers and headers for columns. The file is structured as a flat tabular matrix. The structure of the results file comprises nested arrays. For example *M (kNm/m)* column includes several arrays with

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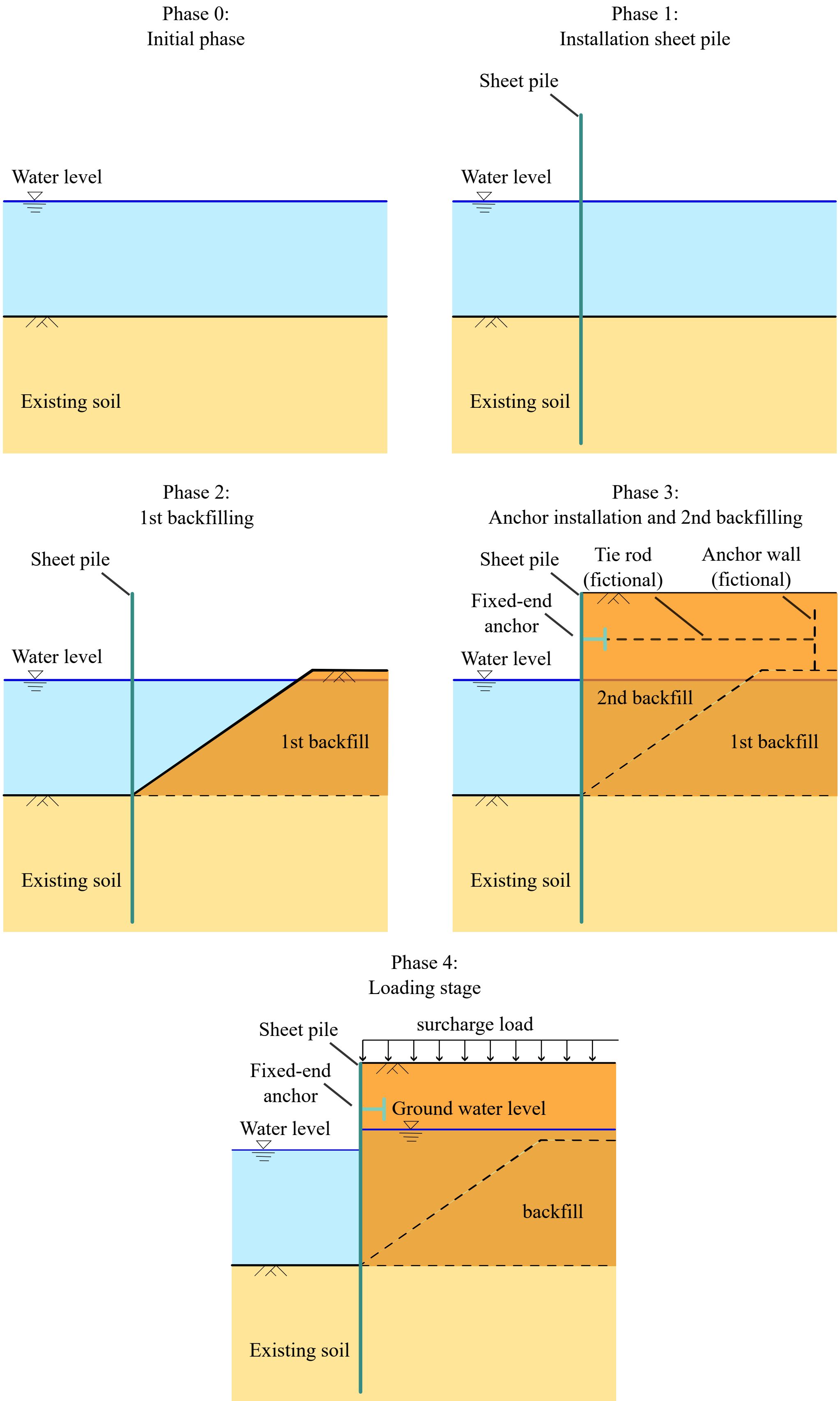

Figure 2: Consecutive calculation phases implemented in FEM model.

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bending moment profiles for each phase in *Phase Plate* column. The formatted entries are organized into tab-separated columns according to the description shown in Table 3.

Table 3: Description of columns in output file

Category	Feature/Column Name	Description / Symbol	Unit
Input Parameters	Retaining height	H_w	m
	Anchor level	Dz_a	m
	Embedment depth	t_w	m
	Sheet pile profile	–	–
	EI sheet pile	Bending stiffness (EI_w)	kNm^2
	EA anchor	Axial stiffness (EA_a)	kN
	Surcharge load	q_s	kN/m^2
	Water level airside	W_a	m
	Ground water level	W_g	m
	Density index existing soil	$I_{D,s}$	%
	Density index backfill	$I_{D,b}$	%
Model performance	Calculation time	FEM computation time	s
	Number of elements	Mesh element count	–
	Number of nodes	Mesh node count	–
Phase trackers	Phase Plate	Phases for saving plate results	–
	Phase Interface/anchor	Phases for saving interface/anchor results	–
Coordinates	Y-Plate	Vertical plate coordinates	m
	Y Interface active	Active side[a] vertical interface coordinates	m
	Y Interface passive	Passive side[b] vertical interface coordinates	m
Structural outputs	N-anchor	Anchor axial force	kN
	Q	Shear force profile	kN/m
	N	Axial force profile	kN/m
	M	Bending moment profile	kNm/m
Deformations	u_x / u_y	Total horizontal / vertical displacement	m
	du_x / du_y	Incremental horizontal / vertical displacement	m
	phi_z / dphi_z	Total / incremental rotation	°
Soil pressures	e_ah / e_av	Active horizontal[c] / vertical[d] earth pressure	kN/m^2
	e_ph / e_pv	Passive horizontal / vertical earth pressure	kN/m^2

[a]Earth side
[b]Airside
[c]Effective normal stresses σ'_N
[d]Shear stress τ_1

Dataset organisation

The databank repository is organised into two files:

- `summary_results_LHS.txt`: Dataset consisting of 4,159 result entries of conducted numerical simulations.
- `QW_H10.0_za2.2_tw4.6_AZ 38-700N_EAa2180100_qs20_Wa3.6_Wg1.0_IDs80_IDb24.full`: Log-file containing commands, which can be used for generating a ready-to-run FEM model in Plaxis 2D.

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The log-file is labeled using an explicit string mapping token sequence corresponding to the selected LHS sample features:

$$\mathrm{QW}\_\underbrace{\mathrm{H}[x_1]}_{H_\mathrm{w}}\_\underbrace{\mathrm{za}[x_2]}_{z_\mathrm{a}}\_\underbrace{\mathrm{t}[x_3]}_{t_\mathrm{w}}\_\underbrace{\mathrm{EAa}[x_4]}_{EA_\mathrm{a}}\_\underbrace{\mathrm{AZ\ XX\text{-}700}[x_5]}_{EI_\mathrm{w}}\_\underbrace{\mathrm{qs}[x_6]}_{q_\mathrm{s}}\_\underbrace{\mathrm{Wa}[x_7]}_{W_\mathrm{a}}\_\underbrace{\mathrm{Wg}[x_8]}_{W_\mathrm{g}}\_\underbrace{\mathrm{IDs}[x_9]}_{I_\mathrm{D,s}}\_\underbrace{\mathrm{IDb}[x_{10}]}_{I_\mathrm{D,b}}.\mathrm{txt}$$

Where each parameter token $[x_i]$ represents the assigned numerical configuration sample. For the sheet pile bending stiffness x_5, the profile tag matches the manufacturer designations (ArcelorMittal Sheet Pilling, 2025).

Run instructions

In order to run a Plaxis model using the log-file, follow the steps:

1. Start a blank Plaxis 2D file
2. Go to: *Expert* → *Run commands...*
3. Open the log-file, copy the content of the file and paste it into the *Commands runner* window in Plaxis
4. Click *Run everything*
5. Go to: *Stages construction* → Click *Calculate*

License

Cerek, K. (2026). Synthetic Dataset of Anchored Backfilled Quay Walls for Surrogate Model Development. Hamburg University of Technology (TUHH). https://doi.org/10.15480/882.17196

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