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# DETERMINING STABILIZATION TIME OF VIBRATING WIRE PIEZOMETERS IN LOW-PERMEABILITY MORaine SOILS

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## ABSTRACT

This study investigates the stabilization behavior of diaphragm-type vibrating wire piezometers installed in low-permeability moraine soils during the staged construction of a railway embankment in Lithuania. Reliable determination of stabilization time is essential for interpreting pore water pressure data and distinguishing installation-related effects from actual hydrological or structural responses. Four piezometers were installed at depths of 1 m and 5 m using the sand pack method. The sensors demonstrated stabilization within a few days, with shallow piezometers responding to rainfall within hours and deeper piezometers exhibiting slightly delayed but consistent trends. The data confirmed that subsequent pressure changes were linked to rainfall, groundwater fluctuations, and embankment loading, rather than delayed sensor response. The results indicate that diaphragm-type piezometers, when properly installed, are suitable for reliable short-term monitoring in moraine environments. This paper provides practical insights for defining stabilization periods in low-permeability soils and supports confident use of piezometric data in design and analysis.

**Keywords:** piezometer stabilization time, vibrating wire piezometer, low-permeability soils, glacial till.

## INTRODUCTION

Piezometers are widely used in geotechnical engineering to measure pore water pressure in soils. Despite decades of use, working with piezometers remains particularly challenging in low-permeability soils, such as glacial tills and clays, due to slow dissipation and the difficulty of determining when stabilization has occurred (Scott & Kilgour, 1967; Simeoni, 2012). Time-lag - the delay between a pressure change in the soil and the sensor's response - is a key parameter in evaluating piezometer performance, especially in clayey and overconsolidated environments (Simeoni, 2012; Wan & Standing, 2014).

Modern vibrating wire (VW) piezometers, especially those with diaphragm sensors and low air entry (LAE) filters, offer several advantages over older technologies. They require only minimal water movement to function, exhibit fast response times, and are well-suited for fully grouted or sand pack installations, which allow multi-level measurements in a single borehole (Sorensen & Simonsen, 2018; Young et al., 2022). LAE filters, in particular, have been found to perform more reliably than high air entry (HAE) filters in saturated soil conditions (Sorensen & Simonsen, 2018). Nevertheless, even with modern sensors, stabilization time remains an open question in practice, particularly in the context of embankment loading or rapid rainfall events.

Lithuania's subsoil is predominantly composed of glacial clays, tills, and silts, which together cover approximately 60% of the country's territory (Klizas et al., 2015). Recent research has confirmed the low hydraulic conductivity of these deposits, with laboratory-measured values ranging from  $k = 0.00001$  to  $0.05$  m/d in many cases (Samalavičius et al., 2024). However, in-situ values may be significantly higher due to differences in stress conditions and sampling disturbance (Simonsen, 2017). Accurately determining pore pressure stabilization in such soils is critical, as delays in response can affect consolidation predictions, design verification, and safety assessments (Kissane et al., 2024).

This study investigates the performance of diaphragm-type VW piezometers installed in moraine soils during the staged construction of a railway embankment in Lithuania. The focus is placed on evaluating pore pressure stabilization time and distinguishing actual hydrological or structural responses - such as rainfall or loading - from post-installation sensor effects. Special attention is given to the practical interpretation of daily pore pressure data and the suitability of sand pack installation methods in glacial soils. The main objective is to determine how quickly reliable pore pressure readings can be obtained after installation in low-permeability soils and to assess whether observed pressure changes are attributable to sensor stabilization or environmental influences.

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MATERIALS AND METHODS

The field investigation was carried out during the construction of a new railway embankment in Lithuania, over a site dominated by low-permeability glacial soils. Pore water pressure was monitored using vibrating wire piezometers to evaluate stabilization time and pressure response under natural and loading-induced conditions.

A total of four diaphragm-type piezometers (Geosense VWP-3000 series) were installed: two at 1 m depth and two at 5 m depth, forming pairs (PZ 1-1 / PZ 1-2 and PZ 2-1 / PZ 2-2). These piezometers belong to the closed-type category, equipped with a low air entry (LAE) ceramic filter and are suitable for saturated soil conditions. All piezometers were installed using the sand pack method, where the filter tip is placed within a zone of clean sand to ensure proper hydraulic contact with the surrounding soil.

The subsoil conditions at the site are typical for glacial terrain in Lithuania. The geological profile (see Table 1) consists of alternating layers of humus, sandy silts, silty clays, and glacial till (saCIL), with measured hydraulic conductivity ranging from  $k = 0.4$  m/d in sandy layers to  $k = 0.00006$  m/d in the moraine clays. The water table was located between 2.3 and 4.2 meters below ground level, depending on location.

Table 1 Geological information of the site with identified soil types.

| Piezometer No.1 |              |                       |                     |              |              |  |
|-----------------|--------------|-----------------------|---------------------|--------------|--------------|--|
| Depth, m        | Thickness, m | Soil symbol ISO 14688 | Permeability k, m/d | Ground water | Piezometer   |  |
| 0.15            | 0.15         | Hu                    |                     | 4.20         | PZ 1-1 (1 m) |  |
| 0.90            | 0.75         | saCIL-SiL             | 0.4                 |              |              |  |
|                 |              | saCIL                 | 0.00015             |              | PZ 1-2 (5 m) |  |
| 3.30            | 2.40         |                       |                     |              |              |  |
| 4.20            | 0.90         | saCIL                 | 0.00006             |              |              |  |
| 4.60            | 0.40         | siSa                  | 0.7                 |              |              |  |
|                 |              | saCIL                 | 0.00006             |              |              |  |
| 5.90            | 1.30         |                       |                     |              |              |  |
|                 |              | Sa-F                  | 6.4                 |              |              |  |
| 7.50            | 1.60         |                       |                     |              |              |  |
| 8.00            | 0.50         | saCIL                 | 0.00012             |              |              |  |
|                 |              |                       |                     |              |              |  |
| Piezometer No.2 |              |                       |                     |              |              |  |
| Depth, m        | Thickness, m | Soil symbol ISO 14688 | Permeability k, m/d | Ground water | Piezometer   |  |
| 0.50            | 0.50         | Hu                    |                     | 2.30         | PZ 2-1 (1 m) |  |
| 1.50            | 1.00         | saCIL                 | 0.4                 |              |              |  |
| 2.30            | 0.80         | saCIL-SiL             | 0.00015             |              | PZ 2-2 (5 m) |  |
| 2.60            | 0.30         | fSa                   | 0.7                 |              |              |  |
|                 |              | saCIL                 | 0.00015             |              |              |  |
| 3.80            | 1.20         |                       |                     |              |              |  |
| 4.40            | 0.60         | fSa                   | 0.7                 |              |              |  |
| 5.00            | 0.60         | saCIL                 | 0.00015             |              |              |  |
|                 |              | saCIL                 | 0.00012             |              |              |  |
| 8.00            | 5.00         |                       |                     |              |              |  |

The embankment was constructed in stages, beginning on 17 October 2024, with fill height measurements recorded monthly. Pore pressure and rainfall were monitored daily during the entire construction and post-installation period. The goal was to assess how quickly each sensor stabilized

and how pore pressure values changed in response to rainfall and increasing embankment load.

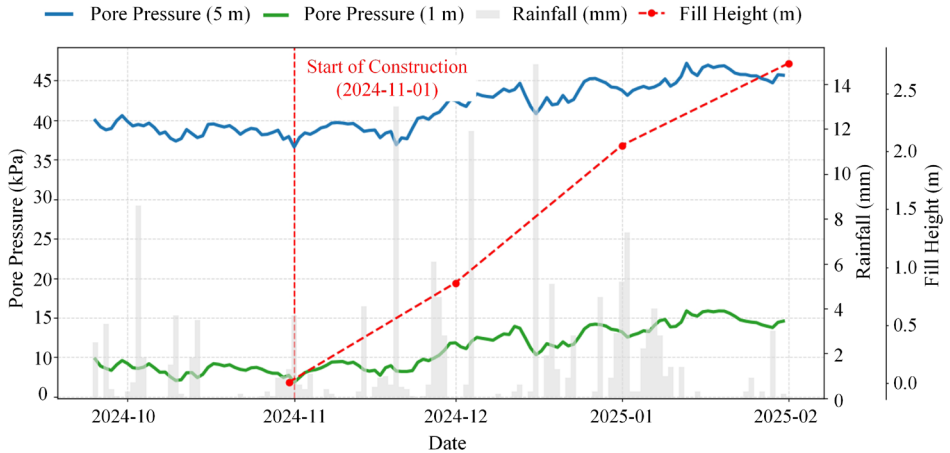
RESULTS

Detailed trends for pore pressure evolution at PZ 1-1 and PZ 1-2 are presented in Figure 1, while corresponding data from PZ 2-1 and PZ 2-2 are shown in Figure 2.

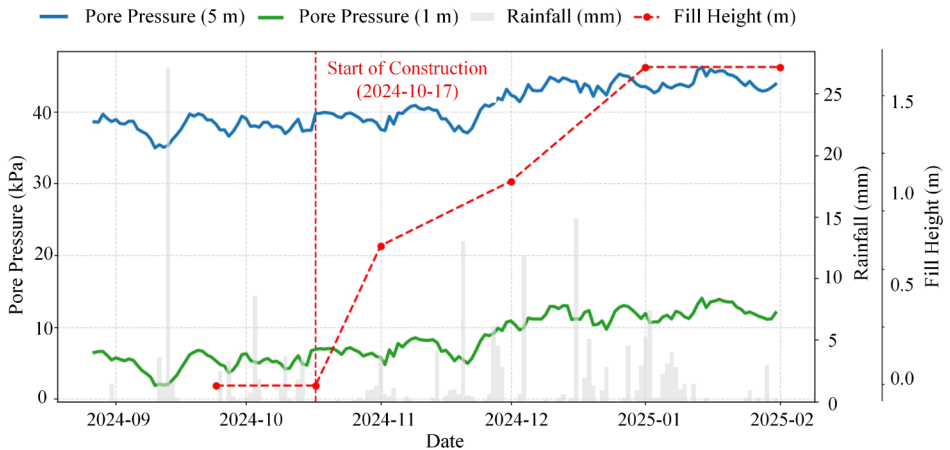
The observed pore water pressure data demonstrate a clear dependence on piezometer installation depth, surrounding soil permeability, and external influencing factors such as precipitation and embankment construction. Shallow piezometers (PZ 1-1 and PZ 2-1), installed in sandy loam layers with relatively high hydraulic conductivity ( $k \approx 0.4$  m/d), exhibited rapid response to rainfall events. In several instances, increases in pore pressure were registered within hours after major precipitation, confirming fast hydraulic connection to the surface and full sensor saturation. This behavior corresponds well with the expectations outlined in Annex A of EN ISO 18674-4:2020, which indicates that saturated diaphragm-type piezometers typically stabilize within a few hours under favorable conditions.

Deeper piezometers (PZ 1-2 and PZ 2-2), embedded in low-permeability moraine clays (saCIL,  $k = 0.00006$ - $0.00015$  m/d), showed a slightly delayed but nonetheless distinct reaction to rainfall and groundwater level changes. Although the pressure variations were more damped compared to shallow sensors, stabilization was still observed within a few days after installation, with no evidence suggesting a multi-week stabilization period. The signal evolution after this point appears to reflect true hydrological conditions rather than ongoing dissipation of installation effects. These observations are further supported by published values for moraine loams in Lithuania (Samalavičius et al., 2024), which report permeability coefficients in the range of  $10^{-6}$  to  $10^{-8}$  m/s (approximately  $0.000086$  to  $0.0000086$  m/d), consistent with the values recorded at the site.

Following the start of embankment construction on 17 October 2024, a clear and sustained increase in pore pressure was observed, particularly in the deeper sensors. This increase developed within several days of load application, indicating prompt excess pore pressure generation. In some cases, a partial dissipation trend was noticeable over the following one to two weeks, suggesting early-stage consolidation in the clayey layers. However, pore pressure values did not return to pre-loading levels, implying the long-term presence of the structural load's effect. These findings confirm that both sensor types responded as expected under varying soil conditions, and that the observed pressure variations are governed by external factors rather than delayed sensor stabilization.



**Figure 1** Pore water pressure variation at piezometers PZ 1-1 (1 m) and PZ 1-2 (5 m) in response to precipitation and embankment loading



**Figure 2** Pore water pressure variation at piezometers PZ 2-1 (1 m) and PZ 2-2 (5 m) in response to precipitation and embankment loading

## CONCLUSIONS

This study focused on the interpretation of pore water pressure data from diaphragm-type vibrating wire piezometers installed in low-permeability moraine soils in Lithuania. The primary aim was to assess sensor stabilization time and evaluate pore pressure response to precipitation and structural loading during embankment construction.

Piezometer stabilization was achieved within a few days in both shallow and deep installations. No long-term drift was observed, and pressure

changes after this period were linked to external hydrological and loading effects.

Shallow piezometers (1 m) in higher-permeability soils responded to rainfall within hours, reflecting rapid hydraulic connectivity with the ground surface.

Deep piezometers (5 m), installed in moraine clays with  $k = 0.00006\text{--}0.00015$  m/d, showed slightly delayed but distinct responses, confirming effective measurement in low-permeability conditions.

Pore pressure increase due to embankment loading was detected within several days after

construction began and partially dissipated over 1-2 weeks, depending on soil type and depth.

The results are consistent with Annex A of EN ISO 18674-4:2020, which indicates that saturated diaphragm-type piezometers stabilize within a few hours under favorable conditions.

These findings support the use of diaphragm-type piezometers for reliable short-term monitoring in moraine environments. The sensors provided stable and interpretable data shortly after installation, enabling confident evaluation of both hydrological and structural impacts.

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