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Analysis of the influence in soil permeability, with the use of high-density drilling fluids applied in the internal edge of drilling rows

Analyse de l'influence sur la perméabilité du sol, avec l'utilisation de fluides de forage à haute densité appliqué dans le bord interne des lignes de forage

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ABSTRACT: Among the most useful methods of gathering geotechnical information from soils beneath the surface are drilling and applying permeability tests in it. The results obtained from such methods provide relevant data that can be used to predict and avoid natural and geotechnical disasters, such as slope and dam failures. A very common practice in drilling tropical soils is the usage of high viscosity fluids, in order to cool down the drilling row, provide stability to the borehole walls and ease the retrieval of samples. However, the use of such fluids causes impermeability in the borehole walls and impacts the hydraulic parameters obtained when the water is injected during the permeability test. A solution for this problem could rely on applying high-density fluids only in the internal edge of the sampling row, implying that no contact between the fluid and the borehole walls occurs. Therefore, this study aims to compare the results from permeability tests executed in the same geological layer, with and without the use of drilling fluids. The expected results indicate that there should not be relevant differences in the results of both methods, hence the fluid will not overflow to the borehole walls.

RÉSUMÉ: Parmi les méthodes les plus utiles pour collecter des informations géotechniques sur les sols sous la surface figurent le forage et l'application de tests de perméabilité. Les résultats obtenus grâce à ces méthodes fournissent des données pertinentes qui peuvent être utilisées pour prédire et éviter les catastrophes naturelles et géotechniques, comme les ruptures de pentes et de barrages. Une pratique très courante dans le forage des sols tropicaux consiste à utiliser des fluides à haute viscosité, pour refroidir la rangée de forage, d'assurer la stabilité des parois du trou de forage et de faciliter la récupération des échantillons. Cependant, l'utilisation de tels fluides provoque l'imperméabilité des parois du forage et impacte les paramètres hydrauliques obtenus lors de l'injection de l'eau pendant le test de perméabilité. Une solution à ce problème pourrait consister à appliquer des fluides à haute densité uniquement sur le bord interne de la rangée d'échantillonnage, ce qui implique qu'aucun contact entre le fluide et les parois du trou de forage n'est établi. Cette étude vise donc à comparer les résultats de plusieurs tests de perméabilité réalisés dans les mêmes strates géologiques, avec et sans utilisation de fluides de forage. Les résultats attendus sont qu'il ne devrait pas y avoir de différences significatives dans les résultats des deux méthodes, raison pour laquelle le fluide ne débordera pas vers la paroi du forage.

Keywords: Permeability test; hydraulic conductivity coefficient; high-density fluids; "quadrilátero ferrífero"; drilling.

1 INTRODUCTION

In order to determine the *in-situ* hydraulic conductivity coefficient (k) of soils, different permeability test methods can be applied, such as the tests executed inside of boreholes or standpipe piezometers (field testing).

In general, the methodology of execution of those tests consists of applying a variation in the water column (rising or falling) through injection or removal of water and measuring the absorbed/removed water volume due to time.

In both engineering and environmental geology study fields, those tests are systematically executed to establish permeability conditions and enable the design and implementation of civil engineering works and environmental projects. Therefore, they are often employed in dams and tunnels projects, also for landfill conceptions, and investigation of contaminated sites, among many other types of projects (ABGE, 2020).

Due to the relation between the execution of field permeability tests and the prospection method applied, it is certain that operational factors may interfere in hydraulic conductivity results. As example, the use of drilling fluids can be mentioned. Under those circumstances, it is common to be required the non-utilization of those fluids in boreholes which are destinated to permeability tests execution.

On the other hand, the use of those fluids is essential to ensure effective drilling operation, since it provides better drilling rates and lower operational costs. Some of the advantages of the usage of drilling fluids stands out: lubrification and cooling of the drilling tools during rotary drilling process; efficient removal of debris inside the borehole; better recovery rates of unconsolidated materials; avoiding overcoming obstructions; and avoiding damages to drilling equipment.

A solution for this matter could rely on applying high density fluids only in the internal edge of the sampling row, implying that no contact between the fluid and the borehole walls is made.

Still, there are few published studies which intend to investigate the relation between the use of drilling fluids and hydraulic conductivity results.

Therefore, the present paper intends to compare the results from permeability tests made in the same geological layer, with and without the use of drilling fluids.

2 OBJECTIVES

The present study aims to stablish and understand the influence of using high density fluids in drilling operations, and the results obtained with permeability tests applied at the same geological layer.

The expected results indicate there should be no relevant differences in the results of both methods, hence the fluid will not overflow to the borehole wall. The methodology consisted of applying the following steps:

- Perforation of two boreholes, with a length of 19.0 m each: SM-01, with non-material recovering and without using high density fluid materials; SM-02, sibling borehole, with material recovering and using high density fluid;
- Execution of geological visual-tactile description of the SM-02 drilling soil samples;
- Carrying out permeability tests inside both boreholes, according to preestablished depth intervals;
- Calculation of the soil hydraulic conductivity coefficient (k) for each test, according to Zangar (1953);
- Comparison of the results obtained for each geological layer, in order to verify how the usage of high-density fluid influenced the k coefficient.

The study area belongs to a mining complex located at "Quadrilátero Ferrífero" geological province, more specifically at Itabirito city, Minas Gerais state, Brazil. Figure 1 illustrates the location of the two boreholes inside the study area.

The boreholes were executed using an hydraulic rotary drilling equipment. The equipment and tools employed at the permeability tests development are listed below:

- Water pump with a minimum 40 L/min capacity;
- 2 water meters (flow range: 10 to 40 L/min);
- Graduated cylinder;
- Threaded funnel attachable to the liner;
- Electric water level meter;
- Graduated bucket;
- Certified metal ruler;
- Stopwatch.

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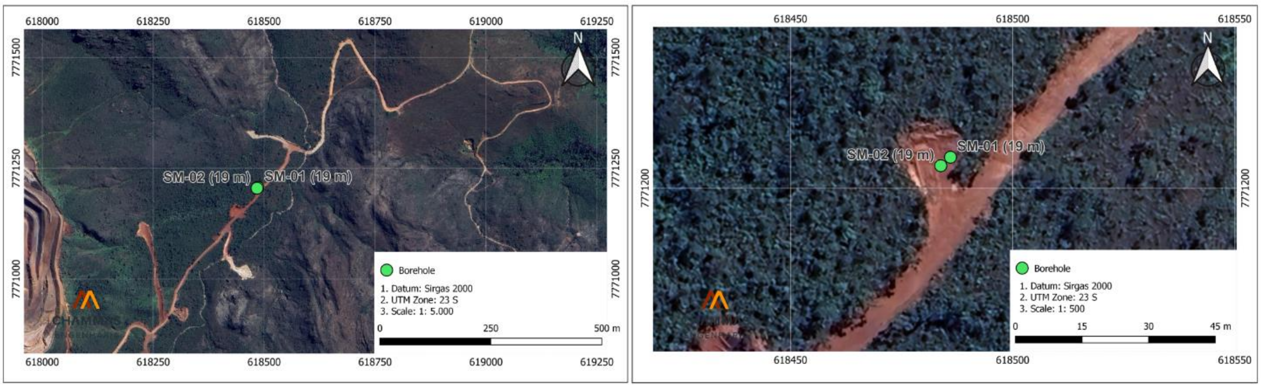

Figure 1. Location of the two boreholes inside the study area (left:1:5.000 scale; right: 1:500 scale).

The tests were carried out holding the water level column inside the borehole through water addiction. The equations proposed by Zangar (1953) allow obtaining the hydraulic conductivity coefficient (k).

For unsaturated strata, k coefficient is calculated using the Equation 1 below:

$$k = \frac{Q}{2\pi L_A\,(2h_1 - L_A)} \cdot \left[sinh^{-1}\left(\frac{L_A}{r_1}\right) - \left(\frac{L_A}{h_1}\right)\right] (1)$$

For saturated strata, k is calculated using the Equation 2 below:

$$k = \frac{1}{C_s r_1} \cdot \frac{Q}{h_1}, where\ C_s = \frac{L_A}{r_1} \cdot \frac{2\pi}{ln\frac{L_A}{r_1}} \qquad (2)$$

where k is the hydraulic conductivity coefficient (cm/s), Q is the steady state flow (cm³/s), h_1 is the head on well (cm), r_1 is the well radius (cm), L_A is the active or uncased length of well (cm) and C_s is the saturated strata conductivity coefficient.

3 RESULTS

Table 1 shows the permeability test results for both drilling holes. The geological description of the soil drilling samples is presented at Table 2 below.

Table 1. Permeability tests results for SM-01 and SM-02.

Test nº	Depth (m)	SM-01	SM-02
1	3.00 – 4.00	1.79E-04	1.51E-05
2	6.00 – 7.00	-	5.20E-06
3	9.00 – 10.00	-	-
4	12.00 – 13.00	2.29E-04	4.00E-05
5	15.00 – 16.00	7.44E-05	1.65E-05
6	18.00 – 19.00	2.49E-07	4.25E-05

Table 2. Geological description of the soil drilling samples (SM-02).

Depth (m)	Description
3.00 – 4.00	Clayey silt
12.00 – 13.00	Fine-to-medium silty sand
15.00 – 16.00	
18.00 – 19.00	Fine-to-medium silty sand (altered rock – quartzite)

Due to operational reasons, it was not possible to execute the test in SM-01 at depths 6.00 m to 7.00 m (test number 2) and 9.00 m to 10.00 m (test number 3- in this case, at both drillholes). Hence, these two intervals were not taken for analysis purposes, since there is no data related. Once the tests executed at the range 18.00 m to 19.00 m (test number 6) covers an altered rock layer, this must be taken in consideration. Figure 2 illustrates the permeability coefficients obtained for each range.

In general, it is possible to notice that the results obtained from permeability tests executed in SM-02 were influenced using high-density fluids, showing a reduction trend of permeability coefficient when high-density fluids were used at the drilling process.

Although, the same pattern was not observed in tests number 6 results (executed between 18.00 m and 19.00 m, covering the altered rock layer). In that case, the permeability coefficient for SM-01 (with high-density fluids) was higher than the result obtained for SM-02 (without using high-viscosity fluids).

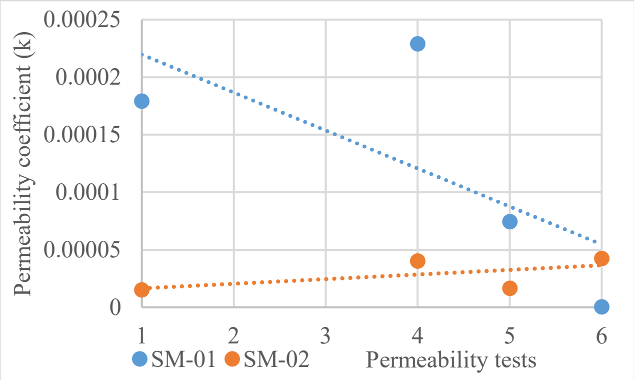

Figure 2. Results of permeability coefficients (k) obtained for SM-01 and SM-02.

4 CONCLUSIONS

Based on the obtained results, it is possible to conclude that using high-density fluids in drilling operations may compromise the permeability test results. The hydraulic conductivity coefficient results, calculated for tests made at SM-01 drilling, show a decrease rate around 10 times when compared to the same tests carried out in SM-02, which highlights the influence of using such fluids.

In order to deepen the analysis of the relation between using of high-density fluids and their influence in borehole walls permeability and hydraulic parameters, more data is necessary. Thus, the authors recommend the study to be continued, applying the same methodology in more samples.

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