# Experimental verification of equations for determining the flow of water in rock discontinuities

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**Abstract** This work is mainly aimed at experimental verification of equations available for the representation of the flow of water through rock discontinuities. To achieve this objective, parallel rock plates of charnockite and slate were submitted, in the laboratory, to a flow of water. Our approach looked at the case of discontinuities with rough surfaces and no fill, both in laminar and in turbulent regime. This verification was performed by laboratory tests on artificial rock discontinuities with different openings and roughness. The experimental results were compared with those obtained by mathematical models in the literature.

**Key Words** flow of water, flow in rock discontinuities

## Introduction

The study of water flow has varied applications in many areas of knowledge. Specifically in civil engineering and mining it is of fundamental importance, since the geological structures are likely to work due to the action and movement of water. Foundations for dams, embankments, underground and open pit mines, lowering water tables and decontamination of aquifers are examples of situations where you need to make estimates of pressure gradients and flow of water for the preparation and implementation of projects.

## Purpose

This work is mainly aimed at experimental verification of equations available for the representation of the flow of water through rock discontinuities. We approached this by examining gaps with rough surfaces as well as those without filling, both in laminar flow regime and in turbulent conditions. These empirical results were then contrasted with mathematical models found in current literature.

## Methodology of laboratory tests

The suggested way to achieve the goals of this study was to compare the values of obtained from laboratory tests with those obtained through calculations of the resistance coefficients carried out according to the theories of Poiseuille (1856), Lomize (1951), Louis (1969), Blasius (1998), and Nikuradse (1999). Obtaining the resistance coefficients tests were performed according to the following equation:

$$f = \frac{4.hf.e.g}{L.U^2} \tag{1}$$

*F*: Loss of load; *L*: Length between piezometers; *e*: Opening of discontinuity; *g*: acceleration of gravity; *U*: velocity of fluid percolation.

The assembly consisted of laboratory rock slabs of slate and charnockite, arranged in parallel and spaced by strips of rubberized cork in order to create artificial discontinuities. The plates had dimensions of 50 × 10cm, with a thickness of about 2cm. The used cork gaskets had 5 mm wide and were placed 1 cm from the edge of the plates, promoting a way of disposing of about 7.5 cm wide. Studied openings were obtained with corks of three different nominal thicknesses (1.6 mm, 0.8 mm and 0.4 mm). At the ends of the specimens formed by two plates and the strips of cork, rectangular nozzles were mounted bolted together, which together with the press, gave strength to the assembly and allowed the entry of water. Two piezometers were connected to one of the plates to determine the load losses. During the tests, temperature measurements, plus volume,

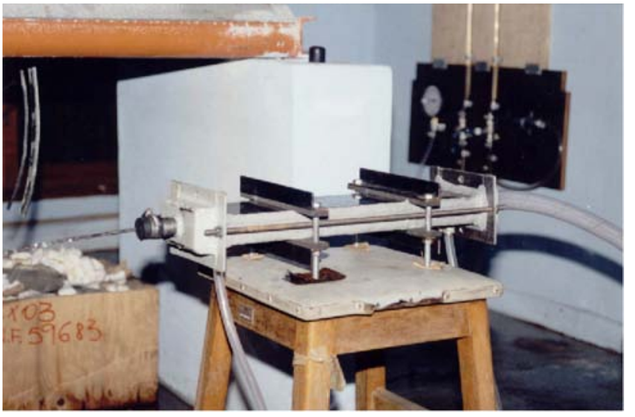

*Figure 1* Overview of test assembled - Body of evidence in the foreground and in the piezometer

time, and pressure differential between the piezometers were obtained. The control flow testing was done with the aid of a gate valve open as the test was performed. For each chosen flow, they obtained the values of the pressure in piezometer located near the entrance of water and in the one located near the exit. Figure 1 shows a typical test set up.

## Results of experiments

The plates were tested in the profiler and values of roughness were obtained. First we present the results for the plates of slate and then to plates of charnockit. The results were plotted on graphs of typical resistance coefficient (f) versus Reynolds number (NR) (Figures 2 and 3). In addition to the points obtained in the tests, lines representing the theoretical expressions that represent the flow were also placed on the chart, so that the experimental results with theoretical calculations can be compared (Figures 4 and 5).

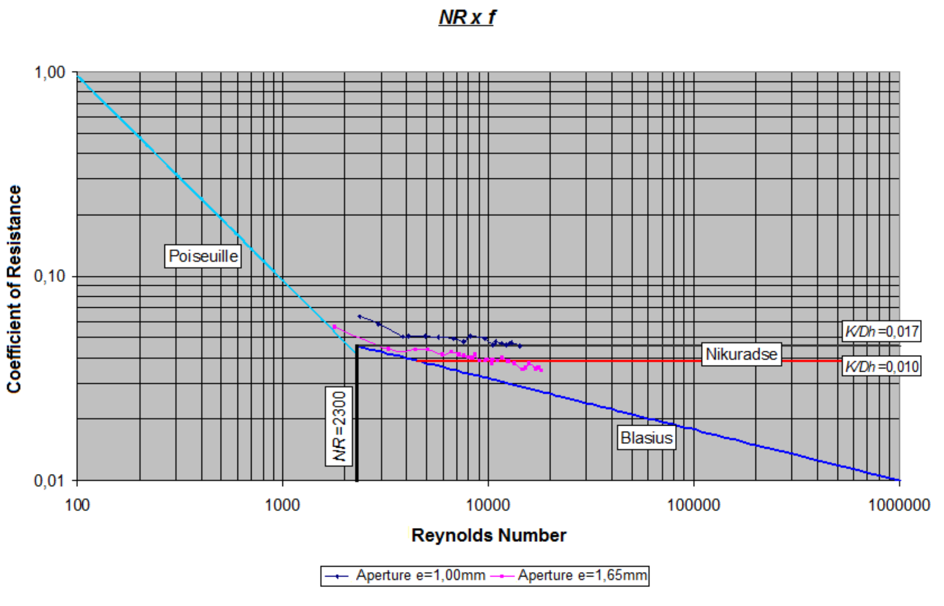


*Figure 2* Experimental results obtained with the plates of slate

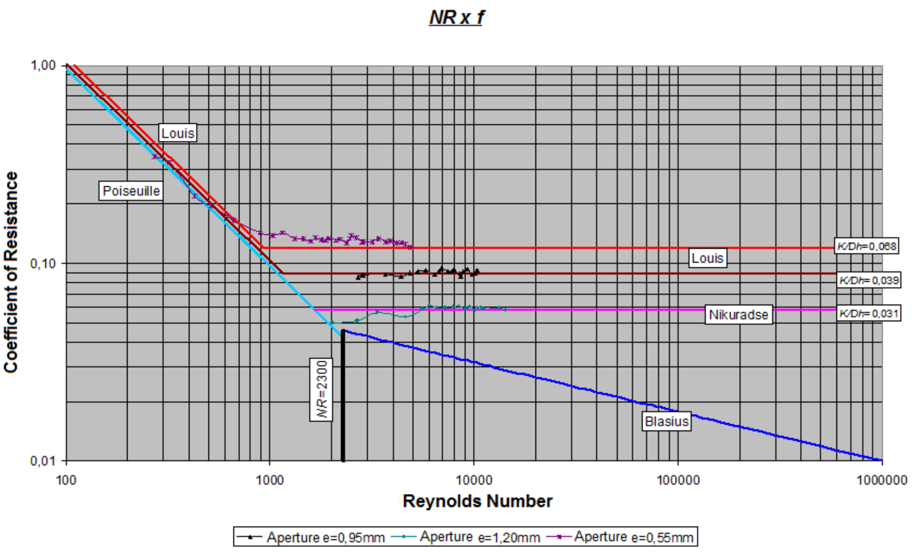


*Figure 3* Experimental results obtained with the plates Charnockite

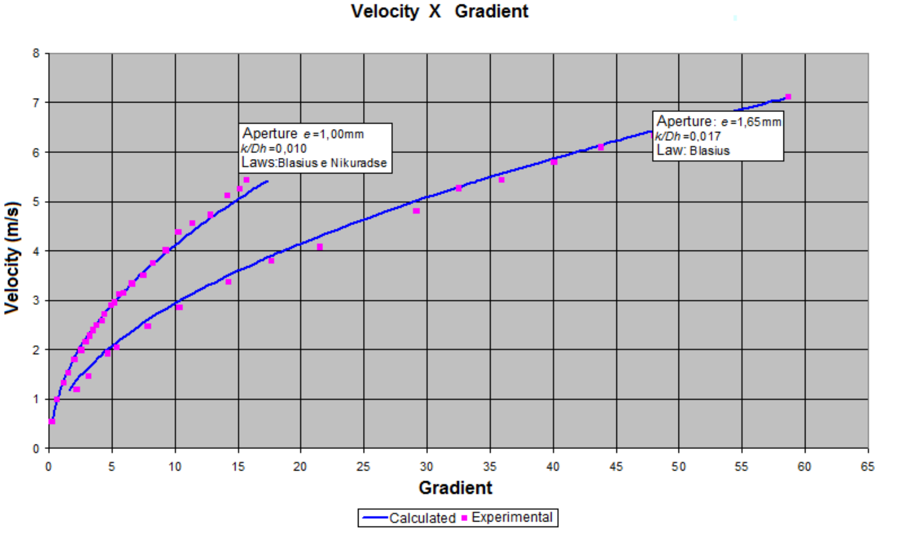


*Figure 4* Experimental results and calculations under the laws of disposing of the slate plates

## Conclusions

The tests showed good approximation between the results obtained experimentally and those obtained through the theories consolidated by Louis. The application of the Lomize equations was not effective as the maximum observed discrepancy was almost of 25%. The reason why the equations are adjusted to Louis better than to those of Lomize is that the conceptions of studies used by these researchers are different. The laboratory models studied by Louis represent better the roughness found in rocks, because they were made with concrete slabs with very rough, parallel faces. Alternatively, Lomize used glass constructions of varied geometries that do not repre-

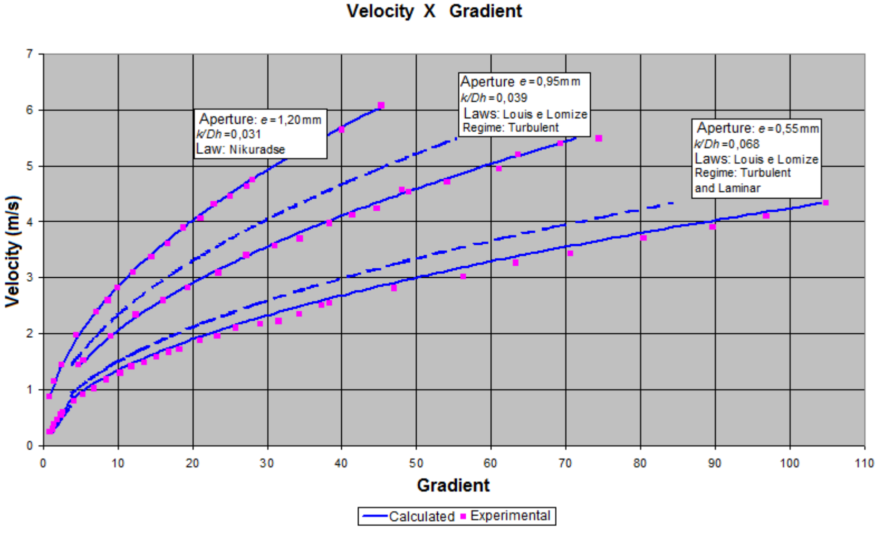


*Figure 5* *Experimental results and calculations under the laws of disposing of Charnockite. plates*

sent so well the case studied by flow discontinuities rock. The tests with plates of slate and charnockite showed maximum percentage difference of 9% and 18% respectively. Deviation values of this size are quite reasonable for applications in geotechnical engineering, as there are many random factors involved.

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