

Name:

Date:

SOIL MECHANICS I LABORATORY CLASS 2: PERMEABILITY, HYDRAULIC CONDUCTIVITY

INTRODUCTION

Permeability κ [m^2] characterises the ability of porous media to be permeated, and is independent of the properties of the permeating liquid. Coefficient of permeability k (hydraulic conductivity) is the coefficient of Darcy's law $v = k i$. The relationship between permeability and coefficient of permeability reads

$$k [\text{ms}^{-1}] = \kappa \gamma / \mu;$$

where μ [$\text{Pa}\cdot\text{s}$] is dynamic viscosity of the liquid. Permeability κ cannot be measured directly it can however be computed from k determined from experiments.

The laboratory class shows the principle of laboratory determination of k in a simple permeameter for highly permeable soils ($k > 10^{-6} \text{ms}^{-1}$). It is aimed at demonstrating Darcy's law, the limit of laminar flow and at verifying the dependence of permeability on porosity. The tested soil will be quartz alluvial sand from Praha - Zbraslav (grains below 0.25 mm and above 2 mm removed, $D_{10} \approx 0.3$ mm, $\rho_s = 2650 \text{kgm}^{-3}$). The dependence of flow velocity on hydraulic gradient will be investigated for both loose and dense sand.

Please note that the lab class *is not* aimed at measurement of k to any standard: the measurements will be carried out using tap water, no provisions will be made for de-airing the water etc.

PROCEDURE

The tested soil is contained in a perspex cylinder of the diameter of 50 mm. The soil of dry mass of 200g is flooded by water. Before and during testing the saturation should be visually checked - if air bubbles are spotted the device should be de-aired.

The volume of percolated water is measured by glass cylinder. Because of the high permeability of the tested soil the flow can be considered steady right from the beginning. The flow quantity during each testing step (gradient) should be sufficient to have reasonable readability (50 to 100 cm^3 is recommended; at the lowest gradients at least 20 cm^3). The pressure heights are determined using a standpipe, the height of outflow (datum) is determined prior to the first testing step.

Dense sand

First permeability will be measured at the lowest achievable hydraulic gradient i (cca 0.3). For further steps the water level in the standpipe is increased gradually to apply i of about $\frac{1}{3}$; $\frac{1}{2}$; $\frac{3}{4}$; 1; 2; 4; 6; 10. The pressure heads, flow quantity and time are registered. Finally permeability is measured under falling head conditions: water enters the specimen from the standpipe and the pressure head decreases during the test. The initial and final positions of water level with respect to the height of outflow is registered together with time interval. At least two measurements are carried out and the average value of k is computed.

Loose sand

After finishing the measurements on the dense sand the specimen is loosened by upward hydraulic gradient exceeding 1. Increase the gradient gradually while observing the soil not to miss the onset of weightless conditions and "liquefaction". After the sufficient loosening (increase of height) of the specimen, determine the specimen height and carry out the measurements at individual gradients similarly to the procedure with dense sand, including the measurements with falling head. At each step determine the height of the specimen (the height may decrease due to the downward water flow).

PROCESSING DATA AND THE REPORT

1. Compute flow quantity, velocity, hydraulic gradients, coefficient of permeability, Reynolds' number R_e and porosity for all measurements at the constant head ($R_e = (D_{ef} \times v \times \rho_w) / \mu$; dynamic viscosity of water μ please find at a text book or tables etc).
2. Plot the dependence of seepage velocity v on hydraulic gradient i for dense and loose sand and from the graphs v vs. i estimate the limits of validity of Darcy's law.
3. Decide whether your measurements were carried out during laminar or turbulent flow. Determine R_e for the limit between laminar and turbulent flow for the tested soil.
4. What was the dependence of coefficient of permeability k on porosity?
5. Compare coefficient of permeability k obtained under constant head conditions with values from your falling head tests.
6. Estimate k from any convenient empiric relationship (e.g., according to Hazen, Terzaghi etc.).
7. Have you succeeded in estimating the gradient at which piping occurred?
8. Further to the above results and plots give your comments to your measurements, accuracy etc.

Name:

Date:

specimen diameter [m]:

cross sectional area [m²):

CONSTANT HEAD

1 Dense sand

sample height [m]	inflow standpipe head [m]	outflow standpipe head [m]	time [s]	volume of water [m ³]	flow quantity [m ³ s ⁻¹]	flow velocity [ms ⁻¹]	hydraulic gradient	coefficient of perm. k [ms ⁻¹]	porosity

2 Loose sand

sample height [m]	inflow standpipe head [m]	outflow standpipe head [m]	time [s]	volume of water [m ³]	flow quantity [m ³ s ⁻¹]	flow velocity [ms ⁻¹]	hydraulic gradient	coefficient of perm. k [ms ⁻¹]	porosity

FALLING HEAD

Diameter of inflow tube [m]:

	initial inflow water level [m]	inflow level [m]	final water level [m]	inflow level [m]	height of outflow [m]	of time [s]	h ₁ [m]	h ₂ [m]	coeff. of permeability k [ms ⁻¹]	
dense sand										average
loose sand										average