Road and Transportation Research Association

Working Group on Aggregates, Unbound Pavements

FGSV

Technical testing regulations for aggregates in road construction

Part 8.3.2

Determination of the infiltration coefficient by the modified vertical tube infiltrometer – In situ method

R 1

TP Gestein-StB

Edition 2012, Translation 2018

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1 Purpose and field of application

The vertical tube infiltrometer described in the following determines the infiltration coefficient for unbound granular base courses in situ. Based on this value, the water permeability of an unbound granular base course can be evaluated.

This method is based on experience gathered mainly from testing of unbound granular base courses. It is fundamentally applicable to other road construction layers, paths, and ways, taking into account the relevant conditions (e.g. the arrangement of the joints on pavements; expected permeability).

The modified vertical tube infiltrometer described in the following is based essentially on the RVS 11.062 [1]. The decisive difference to the vertical tube infiltrometer according to TP Gestein-StB part 8.3.1 is the greater diameter of the base plate, resulting in coverage of a larger test surface.

2 Applicable standards and regulations

DIN 18130-1	“Soil – investigation and testing; Determination of the coefficient of water permeability; Laboratory tests”, 1998 issue
TP Gestein-StB	Part 8.3.1 “Determination of the infiltration coefficient by the vertical tube infiltrometer laboratory method”, 2012 issue

3 Terminology

3.1 Water permeability

Water permeability is the property of a building material or component to allow water to flow through open pores. Water permeability is dependent, among other factors, on the number and geometry of pores, water pressure, water temperature and on the degree of saturation. These influencing factors are subject to fluctuation, so the water permeability of a building material or component is not a constant property. It can therefore only be described or evaluated by taking into account the above parameters. In these technical testing regulation the infiltration coefficient $k_{i(10)}$ is used to describe water permeability.

3.2 Permeability coefficient k

The permeability coefficient k is a parameter for the velocity at which a volume of water flows through a defined area of a building material or component at a given hydraulic gradient. It is determined according to DIN 18130-1 in the laboratory on samples with a degree of saturation of $S \approx 1$ (corresponding to 100 % saturation, S_{max}). The decisive difference from the infiltration coefficient $k_{i(10)}$ described in this technical testing regulation is the degree of saturation at which the test is performed. The infiltration coefficient $k_{i(10)}$ is tested in a partially saturated state, and is normally lower than the permeability coefficient k according to DIN 18130-1.

The permeability coefficient k is – beyond the definition of the term – not discussed further in this technical testing regulation. The explanation serves solely to differentiate the infiltration coefficient $k_{i(10)}$ from the permeability coefficient k.

3.3 Infiltration coefficient $k_{i(10)}$

The infiltration coefficient $k_{i(10)}$ is a parameter for the velocity at which water enters a layer vertically. It is measured by an infiltration test on the surface of built-in laboratory samples or on existing in situ layers at a almost constant degree of saturation (partial saturation) and – converted to a water temperature of 10 °C – indicated in m/s.

4 Principle

During the infiltration test with the vertical tube infiltrometer, the required time is measured during a defined volume of water flows out of a cylinder (vertical tube) into a layer. The measurement area is delimited by a cylinder that is sealed on the surface of the layer so that no outflow of water (at the surface) can occur. According to this test principle, the measurement environment is not watered (see figure 1), so lateral flow also takes place within the layer. The surface of a hemisphere with a radius corresponding to the test area can be assumed with sufficient accuracy as the cross-section through which the flow passes.

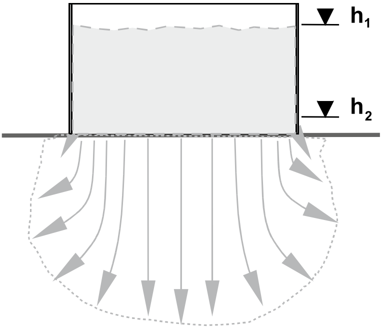

Figure 1: Infiltration principle without watering the measurement environment and with a falling pressure head

Due to a greater water pressure in this method compared to other infiltration methods and its change during testing (decreasing pressure) the hydraulic gradient and the change of pressure have to be considered.

In the laboratory, the infiltration test is performed on a compacted sample.

The infiltrating water volume at a specific time t is depending, among other factors, on the degree of saturation S of the layer to be tested. During the laboratory test according to DIN 18130-1 the air in the sample can be almost entirely displaced by various measures (e.g. flow through the sample from below), thereby attaining the maximum degree of saturation S_{max} ($S \approx 1$). In contrast, during the infiltration test the air in the sample or constructed layer cannot be entirely displaced. Consequently, an infiltration test can only be based on partial saturation ($S < 1$). The infiltration velocity normally decreases during the saturation process. Only when the saturation is constant (S_{max}) the infiltration velocity is also constant. At this particular time the water is flowing at a constant velocity through a layer (see figure 2). The aim of the infiltration method described here is to determine the infiltration velocity at that particular time. It may could also be useful to measure and document the progress of the infiltration during the saturation phase. Depending on the initial degree of saturation S0 and the permeability of the layer, a period of approximately 10 min (for $k_{i(10)} \approx 10^{-5}$ m/s) to > 45 min (for $k_{i(10)} \approx 10^{-7}$ m/s) must be considered for the saturation process.

As complete saturation by water is generally not attained for a layer under in situ conditions, the result of an infiltration test cannot be compared directly to the determination of the water permeability coefficient according to DIN 18130-1. In practice, an infiltration test tends to measure a somewhat lower level.

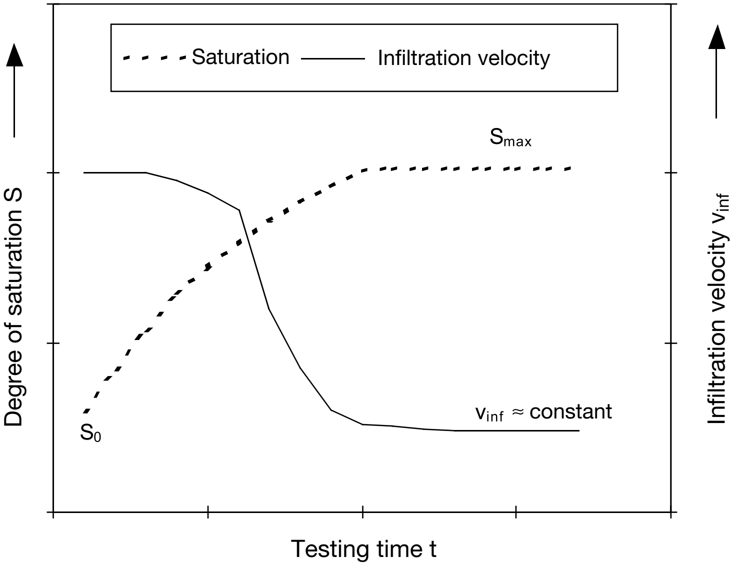

Figure 2: Correlation between saturation state and infiltration velocity dependent on test duration (qualitative)

The water flow rate of water depends on its kinematic viscosity, which in turn depends on temperature. To ensure comparability of results, the infiltration coefficient determined at the measured water temperature must be converted to a reference temperature of 10 °C (see section 7).

5 Equipment

Modified vertical tube infiltrometer (see figure 3) consisting of:

- Ring made of leak-tight foam rubber, inside diameter Ø 250 mm, outside diameter Ø 500 mm, height 10 mm, L-cross-section protruding approximately 1.0 cm on the inside of the ring (see detail Y in figure 3), bonded beneath the base plate.

  Note: The foam rubber ring must be inspected regularly for signs of wear and embrittlement and must be replaced after three years at the latest.
- Base plate as circular ring with inside diameter Ø 250 mm and outside diameter Ø 500 mm, 20 mm thick, non-positive locked and sealed watertight to the base tube.
- Base tube: Transparent cylinder, inside diameter Ø 250 mm, outside diameter Ø 260 mm, height 100 mm.

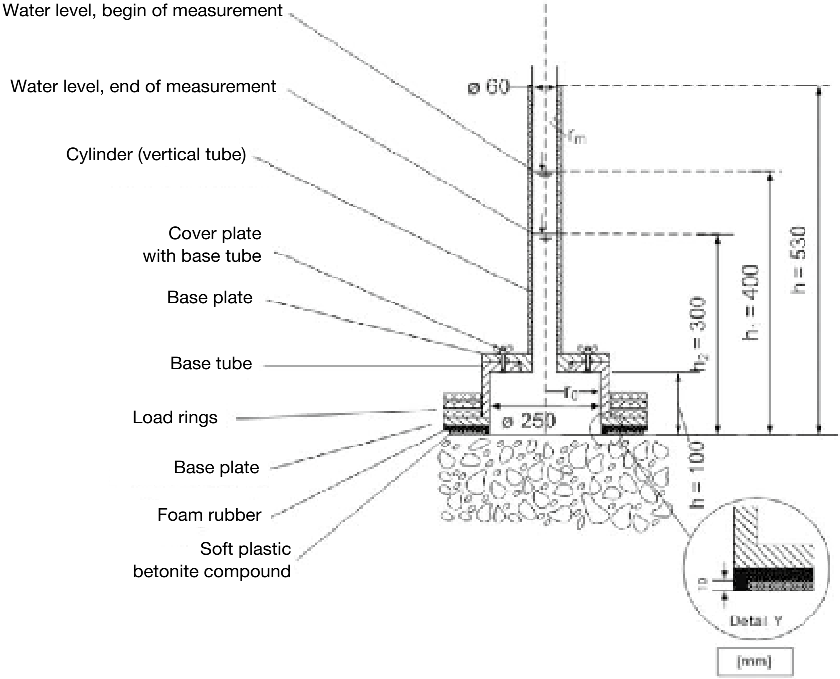

Figure 3: Schematic of the modified vertical tube infiltrometer

- Cover plate: Transparent disk, 25 mm thick, diameter Ø 260 mm, with a central hole (Ø depending on outside diameter of vertical tube) for non-positive, water-tight connection of the vertical tube, including fixture for non-positive, water-tight connection to the base tube (e.g. bayonet lock) and sealing ring.
- Vertical tube: Transparent tube, inside diameter Ø 60 mm, length approx. 400 mm, with measurement marks at 400 mm and 300 mm above the test area.

Sealing materials:

a) Soft plastic bentonite compound or

b) Ring shuttering (e.g. made of steel), inside diameter: 250 mm, outside diameter: approx. 280 to 290 mm, height: approx. 10 to 20 mm and gypsum slurry

Erosion protection:

Washed coarse aggregate, e.g. 5/8 mm, uncrushed or crushed

or

Filter fleece (of adequate water permeability), Ø approx. 400 mm.

Load rings to weigh down the base plate of the modified vertical tube infiltrometer with a total mass of at least 50 kg

Water

Plastic bucket

Stopwatch

Thermometer, accuracy 1 °C

Aids for applying the bentonite compound and producing/processing the gypsum slurry

Writing implement.

6 Execution

6.1 General

The temperature of the layer to be tested and the water temperature must be at least 5 °C. The layer to be tested must be frost-free.

6.2 Preparing the test

The soft plastic bentonite compound is applied to the foam rubber ring of the base plate in a layer of adequate thickness (bead approx. 2 cm thick, see figure 4). Then the base plate is installed with the base tube on the measuring point and the load rings are applied (see figure 5). A washed stone coarse aggregate is placed on the surface of the test area as protection against incoming water. Alternatively, a filter fleece can be placed on the test surface. It must be ensured that the edges of the filter fleece are contacting evenly on the wall of the base tube, so that the bentonite seal is not damaged by the inflowing water.

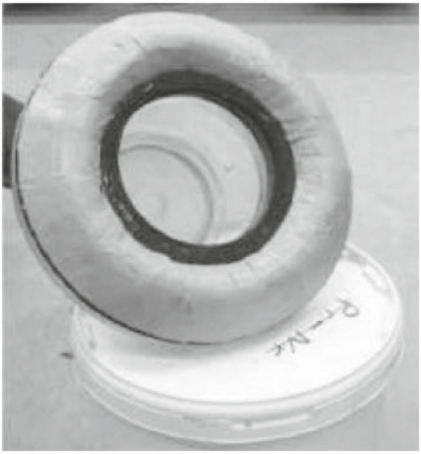

Figure 4: Sealing with bentonite beneath the base plate

Figure 5: Modified vertical tube infiltrometer during in situ testing

The vertical tube unit is connected water-tight to the base tube. For secure sealing of the base plate on the test surface, either dry bentonite powder can additionally be spread in a circular arrangement beneath the base plate, or a pre-treatment of gypsum slurry can be applied, upon which the base tube unit with the bentonite compound is then placed. To avoid a contamination of the test area by applying this additional sealing, it is advisable to mount a template (Ø 250 mm).

After adapting the sealing compound to the base course surface (for approximately 30 seconds) the cylinder is filled with water.

On coarse-grained surfaces, the sealing can alternatively be provided by a gypsum foundation. For this purpose, a ring shuttering (see figures 6 and 7) is placed on the test surface. The shuttering is grouted with gypsum slurry (see figure 8). When doing this, it must be ensured that the gypsum slurry is poured into the shuttering until it is as flush as possible with the top edge of the shuttering. Any protruding gypsum must be scraped off outwards using a spatula, so that a flat surface is created and the test surface is not contaminated by gypsum. When using this sealing method it is not necessary to apply the bentonite compound to the foam rubber ring. The base plate with the base tube is mounted directly on the gypsum foundation with the foam rubber seal.

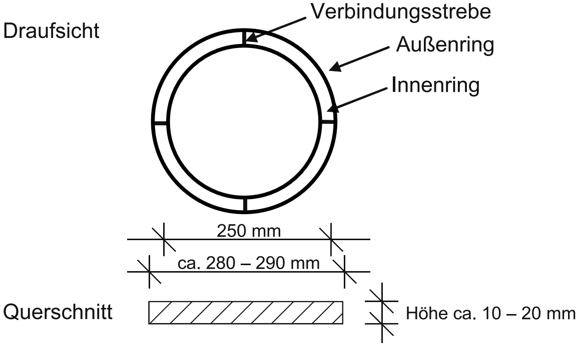

Figure 6: Schematic of the ring shuttering

Figure 7: Ring shuttering for sealing on coarse-grained surfaces

Figure 8: Ring shuttering with poured-in gypsum slurry

6.3 Execution

The vertical tube is filled with water to a few centimetres above the upper measurement mark. The time is measured with the stopwatch taken for the water level to fall between the 400 mm and 300 mm measurement marks and documented to an accuracy of one second. Then the vertical tube must be immediately refilled and the measurement repeated. The test shall be repeated frequently, without time interruptions, until, in three consecutive measurements, the calculated $k_{i(10)}$ value (see section 7):

- fluctuates by not more than ± 1 unit in the first decimal place of the measured value (example measured value: $5 \cdot 10^{-6}$ m/s, permissible measured value fluctuation : $4 \cdot 10^{-6}$ to $6 \cdot 10^{-6}$ m/s) or
- a measurement time during a single test exceeds 45 minutes, or the infiltration coefficient $k_{i(10)}$ is is less than $< 5 \cdot 10^{-7}$ m/s.

If lateral water leakage is observed during the test, the test shall be aborted and repeated after repairing the seal.

7 Evaluation and statement of results

The test is evaluated on the basis of the required time interval in which the water level passing the measurement marks of 400 mm to 300 mm above the top of the sample. According to the Austrian standard ÖNORM B 4422-2 [2] (hemispherical outflow from a circular inflow surface into the half-space without consideration of ground-water), the infiltration coefficient $k_{i(10)}$ is calculated by the following formula:

$$k_{i(10)} = \alpha \cdot \frac{r_m^2}{0.88 \cdot r_0 \cdot \Delta t} \cdot \ln \frac{h_1}{h_2} \qquad [\mathrm{m/s}] \tag{1}$$

$k_{i(10)}$	Infiltration coefficient in m/s, converted to a water temperature of 10 °C
r_m	Radius of the vertical tube in m (= 0.03 m)
r_0	Radius of the outflow surface in m (= 0.125 m)
h_1, h_2	Hydraulic head in m at the time t_1, t_2 (h_1 = 0.4 m, h_2 = 0.3 m), (mean hydraulic gradient: 1.75)
Δt	Time interval $t_2 - t_1$ [s]
α	Temperature correction according to Poiseuille;

$$\alpha = \frac{1.359}{1 + 0.0337 \cdot T_i + 0.00022 \cdot T_i^2} \tag{2}$$

T_i	Water temperature in the infiltration test in °C

With the vertical tube infiltrometer dimensions specified in section 5, the result is given by:

$$k_{i(10)} = \alpha \cdot \frac{2.35 \cdot 10^{-3}}{\Delta t} \quad [m/s] \tag{3}$$

The result must be expressed as an integer with exponents of 10.

8 Test report

The test report shall indicate the following:

- Infiltration coefficient $k_{i(10)}$
- Time interval Δt (time in which the water level falls from the upper (400 mm) measurement mark to the lower (300 mm) mark).

The test report should specify the following properties, provided if they can be assigned to the test surface:

- Water content of the layer
- Dry density of the layer
- Degree of compaction

9 Literature References

1 RVS 11.062, Blatt 16: Richtlinien und Vorschriften für das Straßenwesen; Grundlagen, Prüfverfahren, Steinmaterial: „Bestimmung der Durchlässigkeit von Tragschichtmaterial im Zuge der Eignungsprüfung im Labor“, September 2000, Österreichische Forschungsgesellschaft Straße, Schiene, Verkehr

2 ÖNORM B 4422-2 „Erd- und Grundbau – Untersuchung von Böden – Bestimmung der Wasserdurchlässigkeit – Feldmethoden für oberflächennahe Schichten“, Österreichisches Normeninstitut

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