Road and Transportation Research Association

Working Group on Aggregates, Unbound Pavements

Technical testing regulations
for aggregates in road construction

Part 8.3.1
Determination of the infiltration coefficient
by the vertical tube infiltrometer –
Laboratory method

R 1

TP Gestein-StB

Edition 2012, Translation 2018

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1 Purpose and field of application

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

The test layouts according to DIN 18130-1 previously applied in isolated instances proved unsuitable for building material mixtures for unbound granular base courses in practice because the measurement results normally did not provide satisfactory comparability to the infiltration coefficients measured in situ. The laboratory method using the vertical tube infiltrometer replaces the previously applied test layouts according to DIN 18130-1.

The vertical tube infiltrometer described in the following is based essentially on the RVS 11.062 [1].

2 Applicable standards and regulations

DIN EN 13286-2   "Unbound and hydraulically bound mixtures – Part 2: Test methods for laboratory reference density and water content – Proctor compaction"

DIN 18130-1   "Soil – investigation and testing; Determination of the coefficient of water permeability; Laboratory tests", 1998 issue

TP Gestein-StB   Part 8.1.1 "Determining Proctor density", 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.
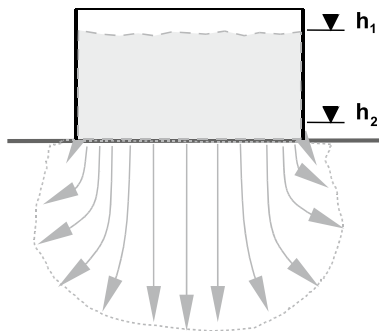

Figure 1: Infiltration principle without watering the measurement environment and with a falling pressure head

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 ≈ 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 $k_{i(10)} ≈ 10^{-5}$ m/s) to > 45 min (for $k_{i(10)} ≈ 10^{-7}$ m/s) must be considered for the saturation process.
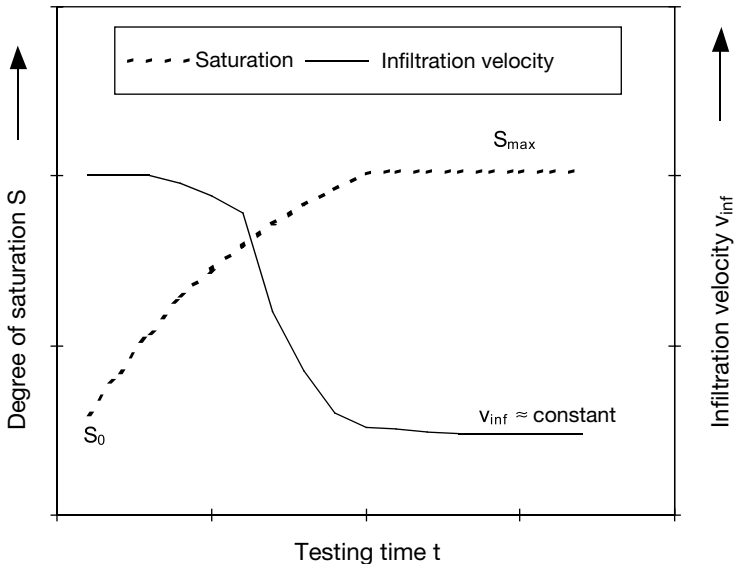
Figure 2: Correlation between saturation state and infiltration velocity dependent on test duration (qualitative)

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 8).

5 Equipment

Vertical tube infiltrometer (see figure 3) consisting of:

– Ring made of leak-tight foam rubber, inside diameter Ø 140 mm, outside diameter Ø 300 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 140 mm and outside diameter Ø 300 mm, 20 mm thick, non-positive locked and sealed water-tight to the base tube.
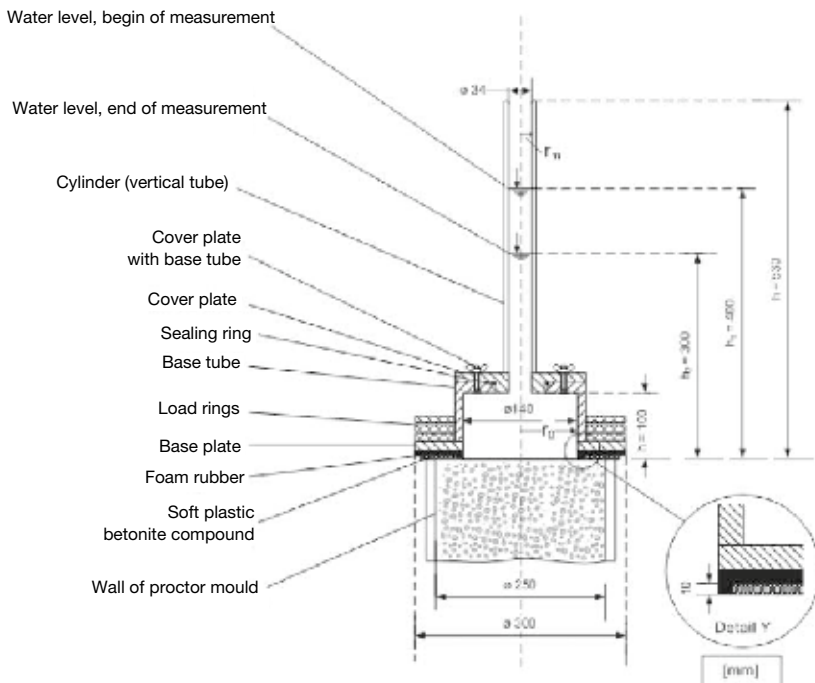
Figure 3: Schematic of the vertical tube infiltrometer

– Base tube: Transparent cylinder, inside diameter Ø 140 mm, outside diameter Ø 150 mm, height 100 mm.

– Cover plate: Transparent disk, 25 mm thick, diameter Ø 150 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 34 mm, length approx. 400 mm, with measurement marks at 400 mm and 300 mm above the test area.

Compaction device as per DIN EN 13286-2

Proctor cylinder as per TP Gestein-StB, part 8.1.1, table 1, row 6 (mould C)

Proctor cylinder base plate, perforated with at least 50 holes Ø 3 mm, distributed evenly across the plate cross-section

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

Soft plastic bentonite compound

Load rings to weigh down the base plate of the vertical tube infiltrometer with a total mass of at least 40 kg

Water

Stopwatch

Thermometer, accuracy 1 °C

Writing implement

6 Sample preparation

Generally, the test is performed with the optimal water content as determined in the modified Proctor test. If the test is to be performed on a removed sample or on a building material mixture in the as-delivered state, the modified compaction must be carried out with the existing water content.

The perforated base plate is placed in the proctor mould C. The test material (required sample quantity approx. 30 kg) must be densificated in the Proctor mould C with modified Proctor compaction energy according to TP Gestein-StB part 8.1.1 with a water content w of $0.8 \bmod w_{Pr} < w < \bmod w_{Pr}$. The surfaces of each compacted layer must be carefully roughened before compacting the next layer. The mass of sample material to be compacted is estimated for each layer such that the last layer is installed as flush as possible with the cylinder rim, at most 5 mm below. After measuring the sample height, the volume of the sample is calculated. The masses necessary to determine the attained density must be calculated within an accuracy of 10 g.

7 Execution

At a maximum of one hour after compaction, the base tube (without vertical tube unit) of the vertical tube infiltrometer is placed on the surface of the sample. Previously an adequately thick layer of bentonite (bead approx. 2 cm thick, see figure 4) is applied evenly to the foam rubber surface of the base plate. The bentonite shall not be allowed to penetrate beneath the foam rubber protrusion onto the test surface (Ø 140 mm). For secure sealing, a layer of dry bentonite powder can additionally be applied to the sample surface, upon which the test cylinder with the bentonite is then placed (see figure 5).

Figure 4: Sealing with bentonite beneath the base plate

Figure 5: Applying the bentonite powder to the sample surface

After the base tube has been mounted, the load rings are placed on the base plate (see figure 6). An approximately three cm thick layer of filter material (e.g. 5/8 m) shall be spread on the surface of the test sample as protection against incoming water. The vertical tube unit is connected water-tight to the base tube.

Mains water should be used for testing. The water should be equal to room temperature with an accuracy of in ± 1 °C.

The infiltration test shall be performed after a maximum of one additional hour. The vertical tube infiltrometer is filled with water, and the time is measured taken for the water level to fall between the 400 mm and 300 mm measurement marks and documented to an accuracy of one second. The test shall be repeated frequently, without time interruptions, until, in three consecutive measurements, the calculated $k_{i(10)}$ value (see section 8)

– 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.

Figure 6: Vertical tube infiltrometer on Proctor mould (mould C) with load rings

8 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:

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

$k_{i(10)}$ Infiltration coefficient in m/s, converted to a water temperature of 10 °C

r_m Radius of the vertical tube in m (= 0.017 m)

r_0 Radius of the outflow surface in m (= 0.070 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:

$$k_{i(10)} = \alpha \cdot \frac{1.35 \cdot 10^{-3}}{\Delta t} \quad [\text{m/s}] \tag{3}$$

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

9 Test report

The test report shall indicate the following:

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

– Water content and dry density of the compacted test sample

– Time interval Δt (time in which the water level falls from the upper (400 mm) measurement mark to the lower (300 mm) mark).

10 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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