Performance of infiltration swales with regard to operation in winter times in an Alpine region

Performance des noues d'infiltration au regard de leur fonctionnement hivernal dans une région alpine

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RÉSUMÉ

Sous les climats froids, les conditions hivernales influencent significativement les performances des dispositifs d'infiltration des eaux de pluie. Le sol gelé et le stockage de l'eau par la neige modifient leur fonctionnement. Cet article traite de l'étude du fonctionnement hivernal d'une noue végétalisée par le biais de mesures sur site et en laboratoire.
L'étude sur site d'une noue végétalisée sur un parc de stationnement dans les Alpes montre que la noue a bien rempli ses fonctions. Bien que la couche supérieure ait été gelée pendant quelques temps, la capacité de stockage de la noue était suffisante pour contenir l'eau de pluie jusqu'à l'amélioration des conditions météorologiques. Le sol jouant un rôle de tampon pour adoucir la température extérieure, les 20 cm de sol en dessous de la surface n'ont gelé que sur une période d'une semaine. La maintenance hivernale s'est révélée poser problème, car avec la neige du parking, une grande quantité de graviers et de fines particules s'était déposée à une extrémité de la noue, diminuant significativement la conductivité hydraulique à ce point.

Les tests en laboratoire, avec des colonnes de sol, ont montré une augmentation du temps d'écoulement au travers des colonnes associée à une réduction de l'humidité du sol. Avec des températures de sol inférieures à 0°C, la conductivité hydraulique diminuait lorsque l'humidité initiale du sol augmentait. Dans l'ensemble, la conductivité hydraulique était optimale autour de 0°C quel que soit le degré d'humidité du sol. Toutefois, à -5°C le coefficient de conductivité hydraulique était toujours au moins au dessus de 10^{-6} m/s, donc dans la plage de conductivité hydraulique tolérée spécifiée dans les recommandations nationales. Cependant, il a été constaté que la manipulation du sol influençait fortement les résultats. Les résultats indiquent que dans les régions alpines, le fonctionnement des noues d'infiltration est satisfaisant en conditions hivernales, malgré une diminution des performances.

ABSTRACT

In cold climate regions winter conditions significantly influence the performance of stormwater infiltration devices. Frozen soil and water storage by snow changes their operation. In this paper winter operation of a grassed infiltration swale was investigated using on-site and laboratory measurements.

The field investigation of a grassed swale at a parking place in an Alpine region showed that the swale fulfilled its function properly. Although the top layer was frozen for some time, the storage capacity of the swale was sufficient to store the precipitation until the conditions improved. The soil attenuated the air temperature, at 20 cm below ground surface the soil was only frozen for one week. Winter maintenance proved to be a problem, together with the snow from the parking place a lot of gravel and fine particles were deposited at one end of the swale. This decreased the hydraulic conductivity at that point significantly.

The laboratory tests with soil columns showed an increase of flow time through the soil column with decreasing soil moisture content. For soil temperatures below 0°C the hydraulic conductivity was reduced for increasing initial soil moisture contents. All in all the hydraulic conductivity was best around 0°C for all soil water contents. However, also at minus 5°C the coefficient of hydraulic conductivity was always at least above 10^{-6} m/s, thus within the range of tolerated hydraulic conductivity specified in the national guidelines. Nevertheless, the handling of the soil was found to have high influence on the results. The results indicate that in the Alpine region infiltration swales operate sufficiently under winter conditions although with decreased performance.

KEYWORDS

Stormwater infiltration; infiltration swale; winter operation; soil moisture; soil temperature; infiltration performance

1 INTRODUCTION

On-site infiltration of runoff from sealed surfaces like traffic areas is common practice to reduce stormwater runoff. Various studies of natural soils have shown that in cold climate regions because of soil frost until the end of winter seepage water is reduced. Surface runoff and seepage water are influenced significantly by the presence of pore and basal ice as well as snowmelt intensity (Bayard et al., 2005). Sutinen et al. (2008) found that snow melt water infiltrates into frozen soil probably through air-filled macro pores. Ice lenses or concrete frost can block the soil completely, however, with granular or porous frost the infiltration capacity can be the same or even better than unfrozen (Muthanna et al., 2007a). Al-Houri et al. (2009) investigated the effect of dry period length prior to freezing and found that the infiltration rate of the soil was the less reduced the longer the dry period was. The pre-freezing soil water content is likely the most important factor which governs the infiltration rate of frozen soils, whereas increasing soil water content results in decreasing infiltration rates. Seyfried and Murdock (1997) used air permeability tests in order to simulate ice blockage effects with soil hydraulic models. Zhao and Gray (1999) modelled for different textures the water and heat transport taking into account phase changes in frozen soils. It is easily understood that winter strongly influences stormwater treatment in cold climate regions because of ice formation in treatment systems, reduced biological activity, increased water density and frozen soils (Oberts, 2003). Muthanna et al. (2007a) and Backstrom (2003) demonstrated that vegetated infiltration devices remove pollutants, especially those bound to particles, also during winter and can thus be used as storage facilities for polluted snow. In the design process the snow, especially the sudden release of stored water during its melting, has to be taken into account (Muthanna et al., 2007b). The size of decentralised infiltration devices is usually determined with simple calculation formulas on basis of statistical rain data, i.e. intensity-frequency-duration relations. In winter the conditions in colder regions differ widely from the conditions on which the design guidelines are based. Thus investigations are needed to confirm their proper operation under such circumstances.

In this paper we investigated the magnitude of the winter's impact on a grassed infiltration swale located in Tyrol, Austria to drain runoff from a parking place. The soil moisture and soil temperature were measured as well as the status of the swale surface documented. Additionally, laboratory tests of infiltration performance with the soil from the swale were conducted using soil columns.

2 MATERIALS AND METHODS

The investigated infiltration swale covered an area of about 180 m² with a medium width of 2 m and drained an asphalt paved area of about 1600 m² consisting of 61 parking lots and 2 aisles. Therefore the relation of infiltration versus runoff contributing area was below 10. The parking place is used for staff and visitors of the University of Innsbruck. During the winter season one part of the infiltration swale is regularly used for local snow deposit due to missing storage area. Because the investigations focused on hydraulic aspects there was no need to document traffic load. To investigate the infiltration performance laboratory and field tests were conducted. In order to emulate winter conditions the laboratory tests were carried out in a cold chamber. Additionally, sensors measuring the soil moisture content and the soil temperature were built into an existing infiltration swale which is operated approximately since five years. The data derived from the laboratory and the field tests is evaluated with regard to the hydraulic behaviour under winter conditions in an Alpine region.

2.1 Hydraulic conductivity of the infiltration swale

The infiltration performance of soils mainly depends on the pore size distribution and the extent of saturation. Because the soil samples used in the laboratory were disturbed samples it was essential to ensure that the results of the laboratory tests were representative. Therefore the time depending infiltration rate of the swale was determined using a stainless steel double-ring infiltrometer. The diameter of the outer cylinder was 56 cm and that of the inner cylinder 28.5 cm. The movable bar at the top of the cylinders ensures that both cylinders were concentric and was used to drive the double-ring infiltrometer horizontally into the grassed swale. The test procedure was carried out corresponding to DIN 19682-7 (2006). To minimize horizontal infiltration processes the outer ring between the two cylinders was filled with water. After filling the inner ring with water the test started and the water level was measured regularly until the infiltration rate did not change anymore. Due to the spatial heterogeneity and spatial variation of physical characteristics, the infiltration rate was investigated at three different places located at the lowest point of the swale whose cross section had the shape of symmetrical trapezium. In order to work out the impact of soil temperature on the hydraulic conductivity the tests were done in autumn as well as in winter at the same position.

2.2 Soil sample and pre laboratory tests

Due to the objective of this study to investigate the infiltration performance of an existing infiltration swale with regard to winter conditions, the soil for the tests was taken directly from a nearby infiltration swale. This infiltration swale was built according to the Austrian standard ÖNORM B 2506 (2003), which requires a 30 cm thick filtration layer. Therefore the investigated soil came from the first 30 cm of the infiltration swale. Prior to the picking of the soil its bulk density was examined in accordance to the German standard DIN 18152-2 (1999) using a cylinder of defined volume which is driven into the soil to obtain an undisturbed soil sample. The bulk density is needed to ensure that the bulk density of the laboratory soil columns complies with the real world due to its strong impact on the infiltration process.

The particle size distribution was examined according to the German standard DIN 18123 (1996) by means of combined sieve and sedimentation analysis. The mesh size of the sieves used was 6.3 mm, 4 mm, 2 mm, 1 mm, 0.5 mm, 0.25 mm, 0.125 mm and 0.063 mm. The fraction of the particles finer than 0.125 mm was determined afterwards with the soil suspension and a densimeter. With the density of the soil suspension and the immersion depth of the densimeter the referring equivalent particle size can be calculated on basis of Stokes's law. The densimeter was read at the time of 1, 2, 5, 15, 45 minutes as well as 2, 6 and 24 hours after the laboratory test started, respectively the particles included in the suspension started to settle down. Because the density and the viscosity of the water is depending on the temperature of the soil suspension its temperature is recorded additionally.

To prepare the soil for the column tests and to determine its water content the soil was dried in an oven at 105°C until constant weight. The test was conducted according to the German standard DIN 18121-1 (1998). The capability of a soil to adsorb water can be expressed as the mass relation between the water saturated soil and the oven dried soil. Therefore the oven dried soil sample was saturated by adding 100 ml of distilled water. To ensure that all particles get into contact with the water the suspension is mixed gently with a spatula. After 20 minutes the suspension was filtrated in order to separate the excess water from the soil.

To determine its organic content the soil sample was dried in a muffle oven at 550°C until it reached constant weight. The ignition loss according to DIN 18128 (2002) is defined as the mass relation of the muffle dried sample and the oven dried sample.

2.3 Soil column tests

Due to the objective to evaluate the infiltration performance of infiltration swales for cold climate, the test concept is designed with varying soil temperatures and soil moisture contents. As presented in previous studies these parameters are the most significant ones with regard to the infiltration behaviour. Therefore the tests were conducted in the laboratory at room temperature or in a cold chamber at 5°C. The layout of the infiltration tests is summarised in Table 1. To reduce the uncertainties of the test results, which were supposed to be significant because of the intrinsic heterogeneous characteristics of soils, all tests were carried out six times.

soil temperature / soil moisture content	0 %	5 %	10 %	20 %	30 %
-5°C (thawing)		X	X	X	
0°C (constant)		X	X	X	
+5°C (constant)		X	X	X	X
+20°C (constant)	X		X		

Table 1: Layout scheme of the infiltration tests

For each test the temperature of the soil was recorded using a temperature probe which was connected to an EM50 data logger from Decagon Devices Inc. (Pullman, USA) in order to ensure that the actual temperature corresponded with the one chosen according to Table 1. The temperature probe was situated in the centre at halfway of the column.

The infiltration performance of the soil was tested in the laboratory with columns of clear plastic. Laboratory tests were chosen due to their advantage with regard to reproducibility and feasibility. The layout of the columns is illustrated in Figure 1. The entire column was made from clear plastic in order to be able to observe the moving wetting front caused by the penetrating water. The inner clear plastic tube holds the soil and the space between outer and inner plastic tube was filled with ice cubes to set the temperature of the soil at almost constant 0°C.

The base plate of the column had radial openings to ensure that the water drained almost unobstructed above the entire area. The drained water was collected in a graduated cylinder. In order to reduce the reading error due to meniscus effects the weight of the seeping water was measured concurrently.

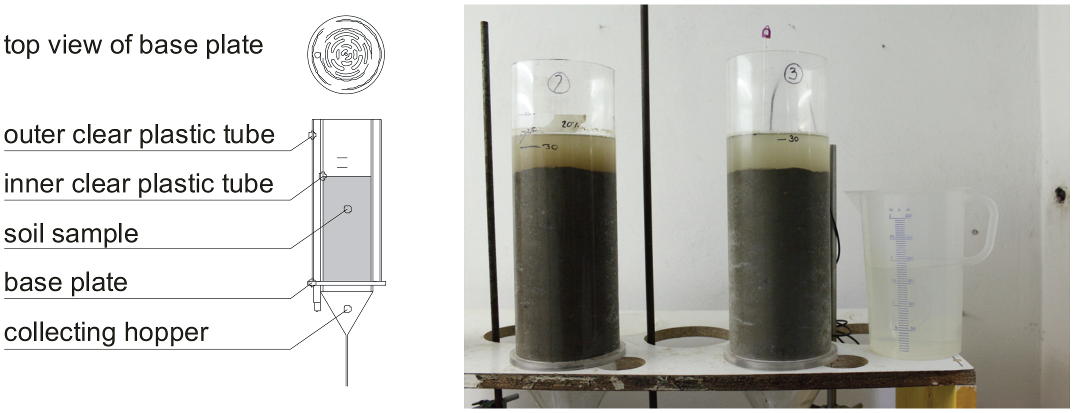

Figure 1: Layout and photography of test column for infiltration performance

Prior to building the soil into the plastic columns the gravel fraction which occurred unevenly was sorted out. Leaving single gravels in the soil would only cause the adverse effect of obtaining not reproducible test results. Afterwards the soil was dried at 60°C until constant weight. Although this temperature is not sufficient to remove all the water even from the pores of small diameter, this temperature was chosen because in pre tests higher drying temperatures caused a significant reduction of infiltration rate. To adjust the desired moisture content the water needed was added to the soil and afterwards the soil water mixture was homogenized. To ensure that all the water was taken up by the soil the soil water mixture was left overnight in a closed container to allow swelling. This soil was built into the plastic columns in layers of 5 cm. To obtain the same bulk density as in the swale each soil layer was compacted with a proctor hammer. In pre tests the proctor hammer was released at a height of fall of 15 cm, whereas in the final tests a reduced height of fall of 7.5 cm was used. The number of blow counts was seven, six blows in the boundary area and one in the centre. Each layer of soil was separated by a plastic mesh to avoid transport of particles of small diameter through the column with the seeping water. Due to the trapping of fine particles at the base of the column this probably had an adverse effect on the test results. The overall height of the soil in the column was 30 cm.

First infiltration tests were conducted at +20°C. These were used to adjust the test procedure and to define the reference level concerning the hydraulic conductivity. In order to ensure reliable test results all tests were designed as triple tests. In all infiltration tests the prepared soil was built into the test column and compacted at room temperature which was around 20°C. The tap water used for infiltration had a temperature ranging from 18°C to 20°C. For the infiltration tests at room temperature 6 l of tap water were used, for all other tests at differing temperatures the total volume of water was 3 l. The test started with filling water onto the soil into the test column until the hydraulic head was 5 cm. Due to the missing grass cover the feeding with tap water had to be done carefully with regard to erosion of the soil surface. Because the rate of infiltration was determined for constant head the water level was kept constant at 5 cm above soil surface. After the water had passed the soil column the effluent was measured over 30 minutes. To take the shape of the effluent hydrograph into account the measurement period was divided into three parts of 10 minutes duration. In the first period the infiltration rate was measured twice a minute, followed by once a minute and every two minutes. To reduce reading errors due to the meniscus effect in the graduated cylinder the water volume was determined additionally gravimetrically. At the end of the infiltration test the saturated soil was weighed.

The infiltration tests at +5°C were carried out in the cold chamber. Prior to testing the plastic columns including the prepared soil were kept for at least 24 hours in the cold chamber in order to ensure uniform conditions with regard to temperature for the entire soil column. To take into account the temperature of rain water in winter season the tap water was also cooled down to +5°C. The rest of the test procedure was identical with the one at +20°C.

For the infiltration tests at 0°C the soil columns were preconditioned in a climatic chamber for at least 24 hours at 0°C. The infiltration test itself took place in the cold chamber at 5°C, because the climatic chamber was not accessible. To prevent the soil column from thawing the space between outer and inner plastic tube was filled with ice cubes. The melt water from the ice cubes was discharged by a valve located in the base plate of the plastic column. Therefore the melted ice cubes had to be replaced regularly. Like in the infiltration tests at +5°C the temperature of the used water was +5°C.

To investigate the infiltration performance in spring when snow is melting and temperatures are rising the soil columns were frozen in the climatic chamber at -5°C for at least 24 hours. The infiltration tests were conducted in the cold chamber to simulate the conditions at spring time.

2.4 Online monitoring of temperature and soil moisture content

The soil moisture content and the soil temperature were measured online from 16.12.2008 to 9.04.2009 in order to assess the results of the soil column tests with regard to how often the boundary conditions of the laboratory tests concerning soil moisture content and soil temperature are true. As data logger the model EM50 from Decagon was used. Additionally, the temperature was measured with iButtons of type DS1921G from Maxim Integrated Products (Dallas USA). Three soil moisture content probes of the type EC-20 and one temperature probe were connected with the EM50 data logger. The moisture probes were built into the undisturbed soil at three different levels, i.e. 10 cm, 20 cm and 30 cm below the ground surface. The maximum depth corresponds with the required thickness of the filtration layer according to ÖNORM B 2506 (2003) . The pit needed for the non-destructive installation of the soil moisture content probes was used to place the additional temperature probes at the defined levels. At each level the temperature was measured with three probes.

Prior to installation the soil moisture content probes had to be calibrated, although the two parameters needed for calibration could be taken from a data base included in the software of the data logger. Water was added to the soil dried in an oven at 105°C until constant weight in order to adjust the soil moisture content to 5 %. This soil was built into a pipe together with the soil moisture content probe and sealed hermetically. Then the soil moisture content was logged for half an hour at an interval of 5 minutes. This procedure was repeated for each soil moisture content, i.e. 10 %, 15 %, 20 % and 25 %. From linear regression of the logged data the two parameters needed for calibration were determined. Due to the soil's heterogeneity the tests for calibration were designed as triple tests.

3 RESULTS AND DISCUSSION

3.1 Soil characteristics

The particle size distribution of the soil is depicted in Figure 2. The mass fraction of particles smaller than 2 mm was about 60 %. Therefore the soil consisted mainly of particles which can be attributed to the sand fraction. Due to the significant fraction of particles smaller than 0.63 mm the soil has to be classified according to DIN 18196 (2006) as a loamy sand with an intermittent particle distribution curve. Because it was observed during the pre-tests that the results of the soil column tests depend on the cycles of drying the particle size distribution was determined with soil directly taken from the infiltration swale and with soil after 10 cycles of drying. The dried soil was characterized by less particles of 1 mm to 6.3 mm size and more particles of 0.63 mm to 0.5 mm size. The shifted particle distribution curve can be used to explain the decrease of hydraulic conductivity with the number of drying cycles.

Additionally to the particle size distribution the capability of water uptake was examined after each drying. The analysis showed a slight trend that the capability to uptake water was reduced with the number of drying cycles. When the adsorbed water was calculated on basis of the dry mass the resulting regression was $y = 0.39x^{-0.08}$. Because of this result the soil was used maximally for three soil column tests.

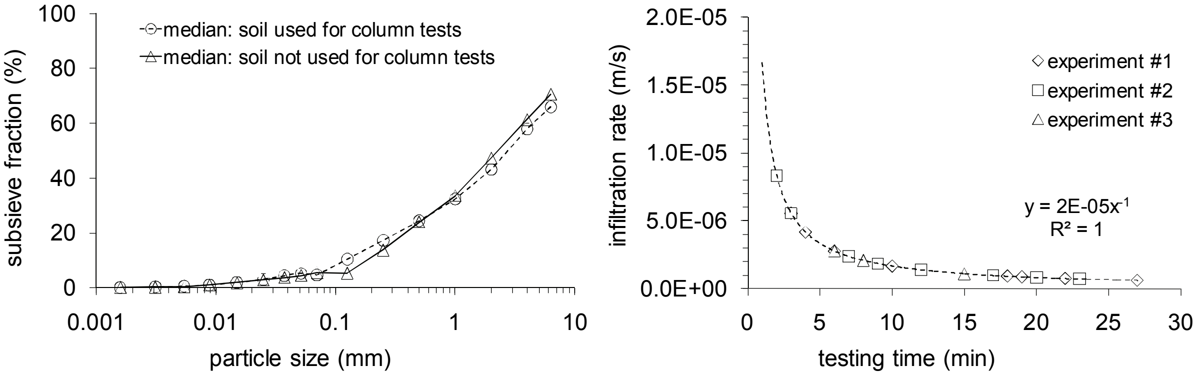

Figure 2: Particle size distribution (left side) and infiltration rate due to the double-ring infiltrometer test (right side)

In order to have a reference value for the hydraulic conductivity of the undisturbed soil the infiltration performance of the swale was also measured using a double-ring infiltrometer. The infiltration rate is illustrated on the right side of Figure 2. The hydraulic conductivity varied between 6.9 10^{-7} m/s and 1.0 10^{-6} m/s. The three experiments showed a close range of hydraulic conductivity. Due to the winter operation there was a part of the infiltration swale used to store the removed snow from the parking lots. At the end of the winter this part of the infiltration swale was covered evidently with fine sediments of dark colour. Because of this obvious blocking the specified area was tested with the double-ring infiltrometer. The hydraulic conductivity of this area was significantly lower than the one measured before the winter.

3.2 Soil column tests

In general there was a high variability with regard to the results of the laboratory tests which can be explained by the significant heterogeneity of soils. In concurrent tests it could be demonstrated that each cycle of drying had an impact on the particle size distribution and the adsorbed amount of water. Despite the careful preparation of the soil columns the only possibility to obtain reliable results is to increase the number of experiments and to limit the number of drying cycles. In total 72 soil column tests were conducted.

On the left side of Figure 3 it can be seen that there was a correlation between initial soil moisture content and travel time for specific soil temperatures. Depending on the initial soil moisture content the soil needed more or less water to reach the state of saturation which is required for the movement of the wetting front. In general for constant temperature flow time through the soil column decreased with increasing soil moisture content. The test results obtained for the soil with 10 % initial soil moisture content and with increasing temperature from minus 5°C were contradictory. The travel time correlated also with the soil temperature. The reason for this effect is probably that in particular the state of aggregation of the frozen pore water had to be changed by the penetrating water. Due to the low temperature (5°C) of the infiltrated water the travel time was mainly needed to melt the frozen pore water.

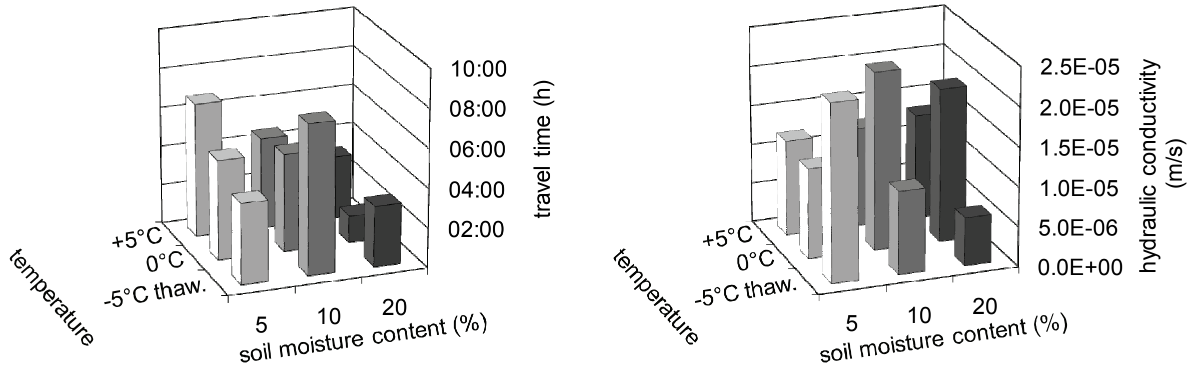

Figure 3: Travel time in the soil column (left side) and hydraulic conductivity (right side) against soil moisture and temperature

Apart from the travel time the infiltration performance can be described by the hydraulic conductivity. After the wetting front had reached the end of the soil column the infiltration process took place under steady state conditions. It can be seen from the right side of Figure 3 that for soil temperatures of 5°C the initial soil moisture content had nearly no impact on the hydraulic conductivity. The highest hydraulic conductivity was obtained for soil of minus 5°C and an initial soil moisture content of 5 %. This observation confirms the results found in literature (Muthanna et al., 2007a). For soil temperatures of minus 5°C the hydraulic conductivity was reduced for increasing initial soil moisture contents. Because of the high thermal capacity of water exceeding the one of soil probably not all soil pores were available for the infiltration process, i.e. one part of the pores was still frozen after the wetting front has passed the soil column. It can be assumed that the ratio of frozen soil pores is higher for soil with higher initial soil moisture content.

3.3 Field data of an infiltration swale

The logged data concerning soil and air temperature is depicted in Figure 4. In the observed winter period there were only 12 days with an air temperature below 0°C all day long. Nevertheless at 44 days the air temperature dropped during the night below 0°C. It needed seven days with air temperature below 0°C at least in the night to change the soil temperature at 10 cm below ground surface from 0°C to values below 0°C. In mid-January when the air temperature increased during the day above 0°C the soil temperature remained below 0°C. Similar, the low air temperature from the January 5th of -10.9°C did not lead to a decreased temperature at 10 cm below ground surface. The lowest temperature in 20 cm below ground surface was 0°C which occurred on 11 days. The difference in temperatures of the two soil layers in 10 cm and 20 cm depth was between -2.3°C and 1.3°C. The difference in temperature of -2.3°C can be explained by the warming of the near-surface layer at 10 cm below ground surface due to relatively high air temperatures. The difference in temperatures of the two adjacent layers 20 cm and 30 cm below ground surface was between -0.75°C and 0.5°C. The lowest temperature at 30 cm below ground surface was 0°C and could be observed on four days. In general the absorptive effect of the soil with regard to the transition of air and soil temperature could be identified. One result is that already the soil at 10 cm below ground surface is frost protected.

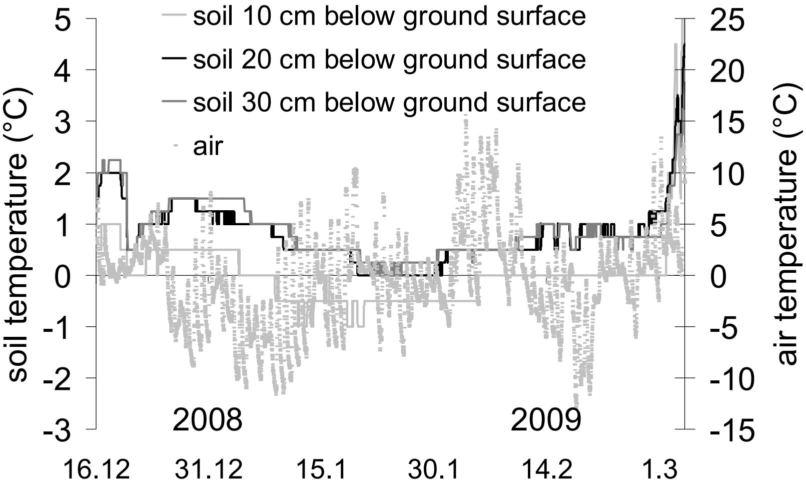

Figure 4: Plotted data of the temperature probes

From Figure 5 it can be seen that the maximum soil moisture content was around 45 %. Furthermore it is obvious that the near-surface layer at 10 cm below ground surface generally was dried up and re-wetted due to rain events more intensely than the surface layers underneath. From the beginning of the measurement period to the first extreme rain event on January 18th the layer closer to the surface at 20 cm below ground surface showed lower soil moisture contents with the dry period than the underneath layer although its initial soil moisture content was higher. Because the soil moisture probe cannot deliver values for temperatures below 0°C due to its measurement principle, no values of the near-surface layer at 10 cm below ground surface could be obtained from January 9th to January 18th. With the rain event on January 18th the wetting front first reached the near-surface layer at 10 cm and finally the layer at 30 cm below ground surface. As consequence the soil moisture content was highest in the upper layer and lowest in the lower layer. The same effect can be observed for the rain events from February 17th and the following days. With rising air temperatures at beginning of April the soil moisture content was decreasing in all layers within the range of 10 % to 16 %. It can be concluded that the longer the travel time the more attenuated the response with regard to drying up and re-wetting.

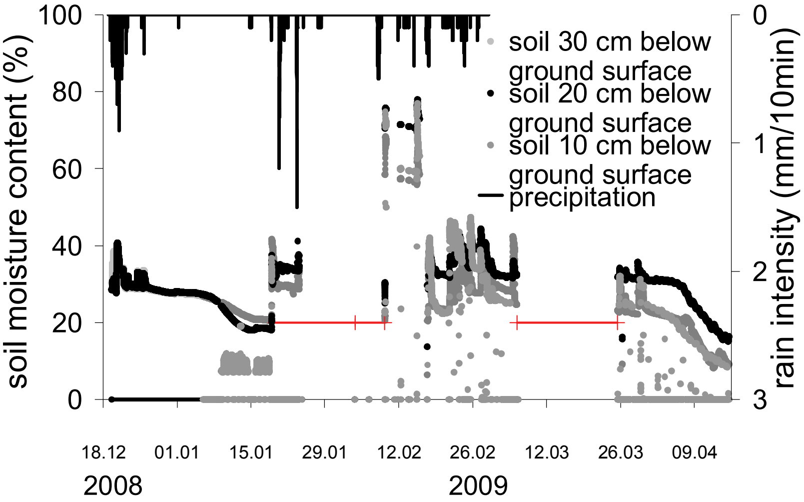

Figure 5: Plotted data of the soil moisture content probes

4 CONCLUSION AND OUTLOOK

In this paper winter operation of a grassed infiltration swale was investigated using on-site and laboratory measurements. In the laboratory experiments widespread tests with soil columns were used which have the advantage to need little amount of material and at the same time lead to reproducible results. In the laboratory experiments not all real world impacts on the ground could be taken into account. Therefore additional on-site measurements were necessary to assess the influence of winter conditions on the infiltration performance of a swale.

The laboratory experiments showed that the travel time depended on the soil's saturation and temperature. In general for constant temperature flow time through the soil column decreased with increasing soil moisture content. For soil temperatures below 0°C the hydraulic conductivity was significantly influenced by the initial soil moisture content. For soil temperatures of minus 5°C the hydraulic conductivity was reduced for increasing initial soil moisture contents. Besides the hydraulic conductivity obtained for soil of minus 5°C and an initial soil moisture content of 5 % was even higher than the hydraulic conductivity of unfrozen soil. Nevertheless, the handling of the soil was found to have high influence on the results. The hydraulic conductivity was best around 0°C for all soil moisture contents. However, the hydraulic conductivity coefficient was always at least above 10^{-6} m/s even at -5°C, which is within the range of tolerated hydraulic conductivity specified in the national guidelines.

The field observations showed no problems for winter operation of the grassed infiltration swale. Although the top layer was frozen for some time, the storage capacity of the swale was sufficient to store the precipitation until the conditions improved. The absorptive effect of the soil with regard to the transition of air and soil temperature could be identified. One result is that the soil at 10 cm below ground surface is already frost-protected. Furthermore, it can be concluded that the longer the travel time the more attenuated the response of the soil with regard to drying up and re-wetting. Winter maintenance proved to be a problem, together with the snow from the parking place a lot of gravel and fine particles were deposited at one end of the swale which decreased the hydraulic conductivity at that point significantly.

The results of both the laboratory experiments and the field measurements confirmed that in the Alpine region infiltration swales designed according to the national guidelines operate sufficiently under winter conditions although with decreased performance. However, infiltration devices are designed on basis of statistical rain data which includes intense rain events of summer seasons. The lower rain intensity in winter and the oversizing by means of safety factors included in the national guidelines compensate the lower hydraulic performance of soils in winter times.

Due to the significant heterogeneity of soils it will be necessary to complement the existing soil column tests with additional laboratory experiments. So far it is not possible to propose an enhanced test procedure with regard to hydraulic conductivity to take winter effects into account. It is planned to simulate the infiltration performance of the investigated grassed swale using a conceptual approach, like models with Horton's equation. The objective of the simulation will be to demonstrate under which circumstances surface runoff due to a reduced infiltration performance can occur.

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