Co-UDlabs

Data Storage Report

CoUDlabs_WP8_T812_IKT_001

Permeable pavement clogging assessment using sediments with different properties

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DOCUMENT TRACKS DETAILS

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Dataset information	
Activity	Joint Research Activities
Dataset ID	CoUDlabs_WP8_T812_IKT_001
Dataset title	Permeable pavement clogging assessment using sediments with different properties
Data sources	Data from laboratory experimental campaign where permeable pavement clogging process was assessed using sediments with different properties. Inflows and outflows characterization and sediment properties are included.
Content	Raw and processed flow and TSS time series: Q [L/s], TSS concentrations [mg/L] Sediment characteristics: Particle size distribution (% volume), Density (kg/m3) Images of the experiments
Formats	csv,
Volume	118 Mb

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Abstract

This dataset includes raw and processed data from a series of laboratory tests that were conducted to develop and assess new and existing methods for analysing pavement performance and to gain insights into how these systems operate during their lifetime. The test method and specification used are based on the standards set by the Deutsches Institut für Bautechnik (DIBt), the German Institute for Construction Engineering. The tests are focused on determining hydraulic permeability and material retention of a cobblestone pavement with permeable joints under different sources of contamination, such as plastic dust and particulate sediments with different granulometries. The work is part of a joint research line between IKT and UDC towards the development of standardised methods to assess the long-term behaviour of different permeable pavement types during their lifetime. Data may be used to increase knowledge on permeable pavement clogging, allowing for developing improved design and maintenance strategies to optimise the long-term performance of permeable pavements.

1. Experimental setup

1.1. Facility description

The IKT irrigation system (rainfall simulator) was used for these tests. The pavement to be tested is installed in a frame of 1 m². The IKT irrigation system consists of three parts (figure 1), a rainfall generator system (A) placed above the frame, a flexible exchangeable/interchangeable frame (B) in which the pavements are installed, a base with a collecting funnel (C) for the water and devices for measuring flow, quantity and quality of infiltrated water and surface water run-off.

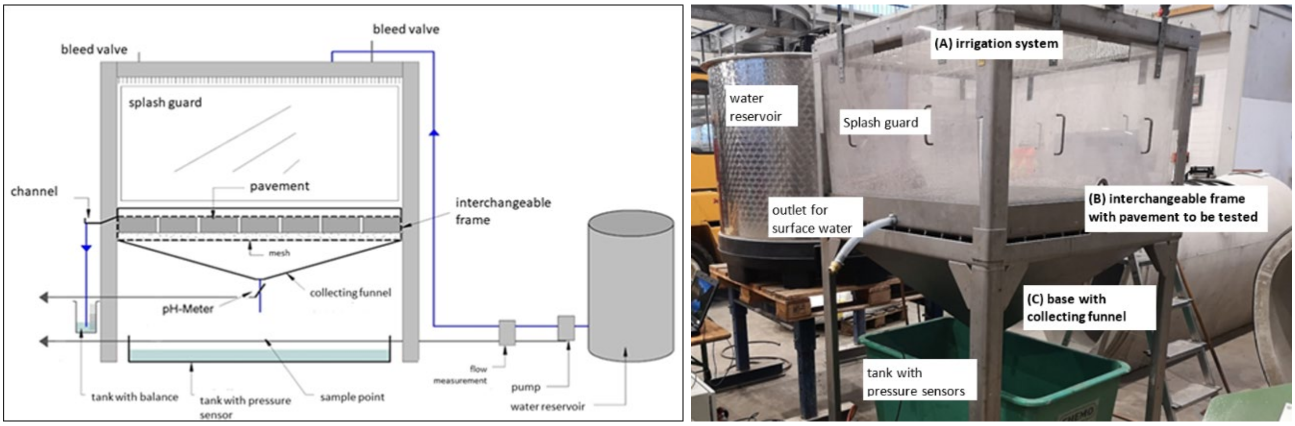

Figure 1. Components of the IKT irrigation system for testing water-permeable pavements and general image.

The interchangeable frame (B), in which the pavement installed, is closed off from below by a fine sieve made of stainless steel (Figure 2). The seepage water that has passed through a pavement can exit through this sieve. The side walls of the standard frame have a height of 12 cm, allowing for 4 cm bedding and 8 cm paving stone. Transport lugs are attached to the outside of the reinforced frame so that the frame, including its contents, can be transported and installed in the rig with the help of a crane. There is a drainage channel at the outer edge of the frame to collect the surface water run-off from across the pavement. The water running off to the side is collected via an outlet and weighed in a container placed on a scale. The weight-time relationship can be used to determine the flow rate. The infiltrated water that leaves the rig through the fine sieve is collected in a geometrically accurately measured trough with a pressure sensor. The flow rate can be determined via the volumetric level-time relationship.

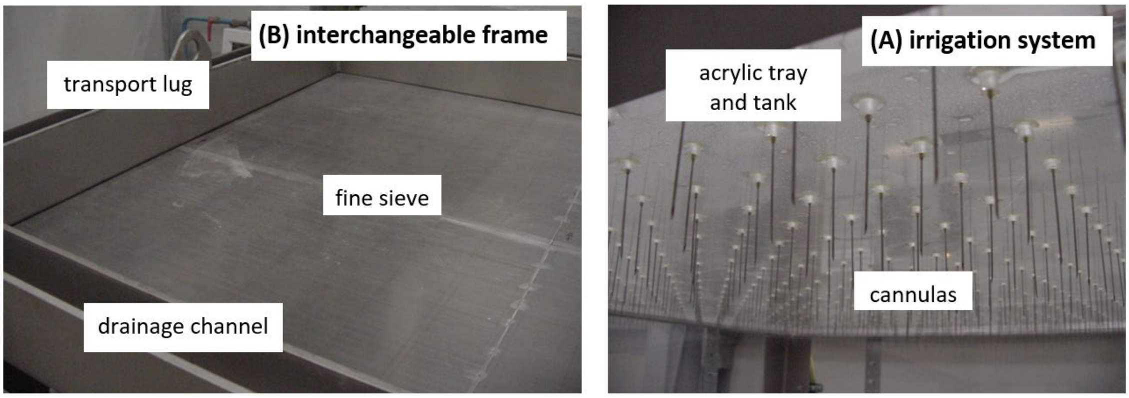

Figure 2. Interchangeable frame (a) and irrigation system (b).

The rainfall simulator system (A) is above the interchangeable frame. It consists of an acrylic tray, in which stainless steel cannulas are embedded at the bottom (Figure 2). The tray is a part of an acrylic tank. The cannulas are located at 4 cm from each other. A total of 625 cannulas enables realistic irrigation of the surface. The cannulas are Sterican® cannulas from the company B. Braun SE with an inner diameter of 0.9 mm, which can be obtained from medical retailers. The water for this sprinkler system is fed into the irrigation system from a supply tank via a centrifugal pump and then drips onto the pavement via the cannulas. The rainfall intensity is measured via a Coriolis mass flow meter in the inlet and controlled via the pump. A coarse filter is located in the inlet of the system to remove particles from the water that could clog the cannulas. The rainfall intensity is controlled by the water pressure. To release the excess air in the acrylic tank, a valve is opened on the top of the sprinkler during filling. When water comes out of the valve, it is closed and the rainfall starts at the desired intensity.

1.2. Permeable pavement

Figure 19 shows the installation layout of paving stones for the tests. A wastewater-treating surface pavement called geoSTON, from Klostermann GmbH & Co. KG, of Coesfeld, Germany, was used for these tests. This product has dimensions of 20/10/8 cm and has a DIBt type approval (Z-84.1-2). According to the manufacturer, the paving stone is made of porous (lightweight aggregate) concrete. The average joint spacing is 5 mm. This corresponds to a joint proportion of approx. 5.9 %. The joint material consists of basalt chippings with the following properties according to TL Gestein-StB 04: grain group 1/3. The bedding material consists of limestone chippings with the following properties according to TL Gestein-StB 04: grain size group 2/5.

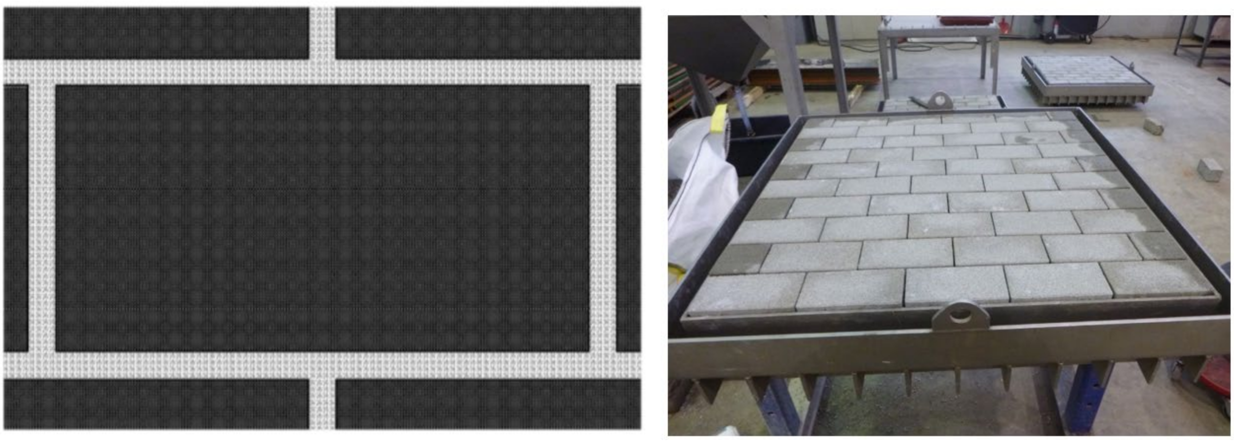

Figure 3: Installation scheme of the paving stones (a) (resource: DIBt) and installed paving stones in the interchangeable frame of the IKT irrigation system (b).

1.3. Sediments tested

Following sediments were used for the tests to cause clogging:

- Millisil dust (MD): This sediment is a standardized Millisil W4 iron-free grinding of processed silica sand typically used in industry and it is used as sediment for the German DIBt approval test. The particle size distribution has a maximum diameter of 250 µm with mean diameter of 64 µm. The density is 2,650 kg/m³.
- Street dust (SD): This sediment was obtained from road dust from parking lots in the UDC campus. The sediment was calcined at 550 °C and classified into sediment fractions to compound a realistic graded road deposit sediment with a d50 of 282 µm. The maximum size was sieved to 1 mm. The density is 2,929 kg/m3.
- Tyre dust (TD): The particle size distribution has a maximum diameter of 200 µm with mean diameter of 64 µm. The density is 1,160 kg/m³. The material is used for is used as a filler and extender in the concrete industry.

Figure 4 shows images of the three sediments used in this work over the pavement after a rain event and their particle size distribution, measured using a laser coulter counter (Beckam-Coulter LS 13 320).

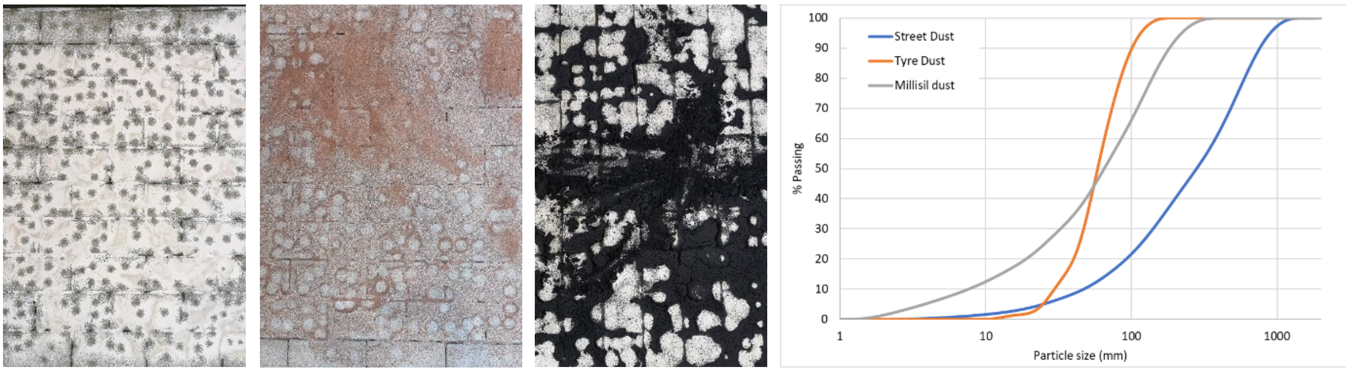

Figure 4. Millisil dust (a), street dust (b) and tyre dust (c) over the permeable pavement surface. Particle size distribution of the three sediments used for clogging tests (d).

2. Experimental procedure

2.1. Test configurations

The pavement installation was used for testing the behaviour of 3 different kinds of sediment regarding clogging. The same experimental setup of pavement and bedding was used for each sediment for comparative purposes. All proceeded tests are shown in Table 1 with the ID used for each experiment during the datasets. The test procedure, which relates to a service life of 40 years, consisted of the following:

- At first the initial permeability was checked for each sediment according to DIBt test standard (requirements: rainfall of 540 l/s*ha => 200 mm/h). The rain duration was set at 30 min to achieve uniform moisture penetration (pre-saturation) of the stone. After this, a rain simulation with a duration of 5 minutes with the same rainfall was made to check the infiltration.
- In test run 2 clogging time was checked. A pollution loading for 10 years was added at the beginning of the test run on the surface (500 g/m²). Then rainfall with a duration of 180 minutes and a rate of 72 mm/h (200 l/s*ha) was applied.

- In test run 3 the permeability after clogging was checked again. According to the requirements a rainfall rate of 100 mm/h has to be applied for 30 minutes followed by a test phase of 5 minutes for testing performance.
- In test runs 4-9 the same test run as in step 1-3 was repeated three times for the addition of 40 years of pollution on the pavement. Test run 5 was a longer antecedent dry period.

Table 1. Test configurations.

Experiment ID	Type of sediment	Test run	Life cycle stage	Cumulative Sediment load (g/m²)	Rain donation (mm/h)	Rain duration (min)	Antecedent dry period (min)
MD_IP	Millisil dust	1	Initial Permeability	0	194.4	35	-
MD_CSL10y		2	10 years pollution load	500	72.0	180	7
MD_PP10y		3	Post Permeability after 10 years	-	97.2	35	11
MD_CSL20y		4	20 years pollution load	1000	72.0	180	7
MD_PP20y		5	Post Permeability after 20 years	-	97.2	35	985
MD_CSL30y		6	30 years pollution load	1500	72.0	180	15
MD_PP30y		7	Post Permeability after 30 years	-	97.2	35	10
MD_CSL40y		8	40 years pollution load	2000	72.0	180	10
MD_PP40y		9	Post Permeability after 40 years	-	97.2	35	7
RD_IP	Road dust	1	Initial Permeability	0	194.4	35	-
RD_CSL10y		2	10 years pollution load	500	72.0	180	15
RD_PP10y		3	Post Permeability after 10 years	-	97.2	35	6
RD_CSL20y		4	20 years pollution load	1000	72.0	180	9
RD_PP20y		5	Post Permeability after 20 years	-	97.2	35	952
RD_CSL30y		6	30 years pollution load	1500	72.0	180	34
RD_PP30y		7	Post Permeability after 30 years	-	97.2	35	9
RD_CSL40y		8	40 years pollution load	2000	72.0	180	11
RD_PP40y		9	Post Permeability after 40 years	-	97.2	35	9
TD_IP	Tire dust	1	Initial Permeability	0	194.4	35	-
TD_CSL10y		2	10 years pollution load	500	72.0	180	12
TD_PP10y		3	Post Permeability after 10 years	-	97.2	35	12
TD_CSL20y		4	20 years pollution load	1000	72.0	180	13
TD_PP20y		5	Post Permeability after 20 years	-	97.2	35	941
TD_CSL30y		6	30 years pollution load	1500	72.0	180	34
TD_PP30y		7	Post Permeability after 30 years	-	97.2	35	9
TD_CSL40y		8	40 years pollution load	2000	72.0	180	11
TD_PP40y		9	Post Permeability after 40 years	-	97.2	35	9

2.2. Rain donation

A Coriolis flow meter (PROMASS 80, Endress + Hauser, S/N: J50AAB02000) was used to measure the rain donation. The device gives flow in mL/s, which are transformed to mm/h which and saved as csv-file with Labview. The calibration consist in passing a certain quantity of water through the Coriolis flowmeter. The mass indicated by the Coriolis flow meter was checked using the Satorius scale. The following are the corresponding calculations:

$$v_s cale = m_s cale / \rho_{(water,15°C)} = (18{,}58 kg \cdot l)/(0{,}999103 kg) = 18{,}597 l$$
$$F_r el = (V_C oriolis - V_s cale)/V_s cale = (18{,}595 - 18{,}597) l/(18{,}597 l) = -0{,}011\%$$

2.3. Infiltration

A pressure sensor from Keller (Typ PRXW36/80748, S/N: 233610.1011) was used to measure the water level in a tank for the infiltration water. We are using the geometry to determine the volume over time. This value was saved as csv-file with Labview. Calibration equations were developed to transform the signal (mA) to volume (m^3) and flow (m^3/s). The tank has a lower base area of 1000 mm x 500 mm and opens upwards symmetrically at an angle of 5.5°. The angle was determined from the ratio of the upper and lower surfaces. The areas were determined using a calibrated tape measure with an accuracy of 0.5 mm from the measured value. This results in a relative total error of 0.15% for the lower surface. With a measured height of 250 mm, this results in a relative total error of 0.14 % for the upper surface. According to the manufacturer's calibration data sheet, the measuring accuracy of the immersion probe (FS <> 10,000 mm) is 0.01% FS, which would mean a relative error of 1.96% for a height of 50 mm. If the error of the lower surface is also assumed as the largest surface error for the upper surface, this results in a relative total error of 0.15% + 0.15% + 1.96% = 2.26% for a water level height of 50 mm when calculating the infiltration quantity.

2.4. Runoff

The surface runoff was weighted with a weight (Sartorius Combics 1 CW1P1-30FE-I, S/N: 16404676). The water weight is measured and considering the water density the volume over time was determined. This value was saved as csv-file with Labview.

2.5. TSS concentation

The samples for the AFS analysis (approx. 1 l volume) were first passed over a 63 µm sieve (metal; diameter 10 cm) in accordance with DIN 38409-2 after the experiment and the sieve passage was filtered by means of vacuum membrane filtration (0.45 µm, cellulose nitrate) (cf. [Dirschke/Welker]). The sieve residue was rinsed out of the metal sieve and also filtered in the same way using vacuum membrane filtration. Dried and weighed filters with a mesh size of 0.45 µm and a diameter of 50 mm were used. The used equipment was a "Vakuum-Filtrationsgerät MV 050, MV 050A/0, mit Schnellverschluss" from Cytiva. The filters were then dried to constant mass at 105 °C and then weighed. The determined masses of sediment on the filters in [mg] were related to the sample volumes in [l] to determine the effluent concentrations in [mg/l]. Thus, two concentrations are available as a result after filtration for each sampling time: Fraction > 63 µm, Fraction 0.45 < 63 µm.

3. Data and result files organization

The dataset includes the properties of the different sediments used, the results of the 27 tests carried out and pictures of the different loads of sediments on the permeable pavement surface. The folder structure is as follows:

- *01_Sediment PSD*: particle size distribution for the three types of sediment used.
- *02_Test results*: test results files. There is a folder for each test included in Table 1 including the following:
    - *Rain donation.csv*: rain inflow measurements including timeseries of rain donation set (mL/s), real rain donation (mL/s) and total test volume (L)
    - *Infiltration*.csv: timeseries of the height (m) of water in the receiving deposited and of the corresponding estimated volume (L) and infiltration rate (mL/s).
    - *Surface runoff.csv*: timeseries of the runoff volume weighted (L) and the corresponding runoff flow (mL/s)

- *Water balance.csv*: total volumes (L) of rain inflow, outflows, samples and estimation of the error (%) of each test.
- *Test_name.pdf*: Summary of each test plotting rain donation, infiltration and runoff flows and including total volumes

- *03_Test pictures*: images of CSL tests (see Table 1) for 10, 20, 30 and 40 years of sediment load and the three types of sediments tested.

Test run 7 rubber dust am 18 April 2023

Volume rain donation [l]	215.8
Volume infiltration [l]	146.5
Volume surface run off [l]	56.6
Volume sample [l]	14.3
Water balance [l]	1.7
Error [%]	0.8

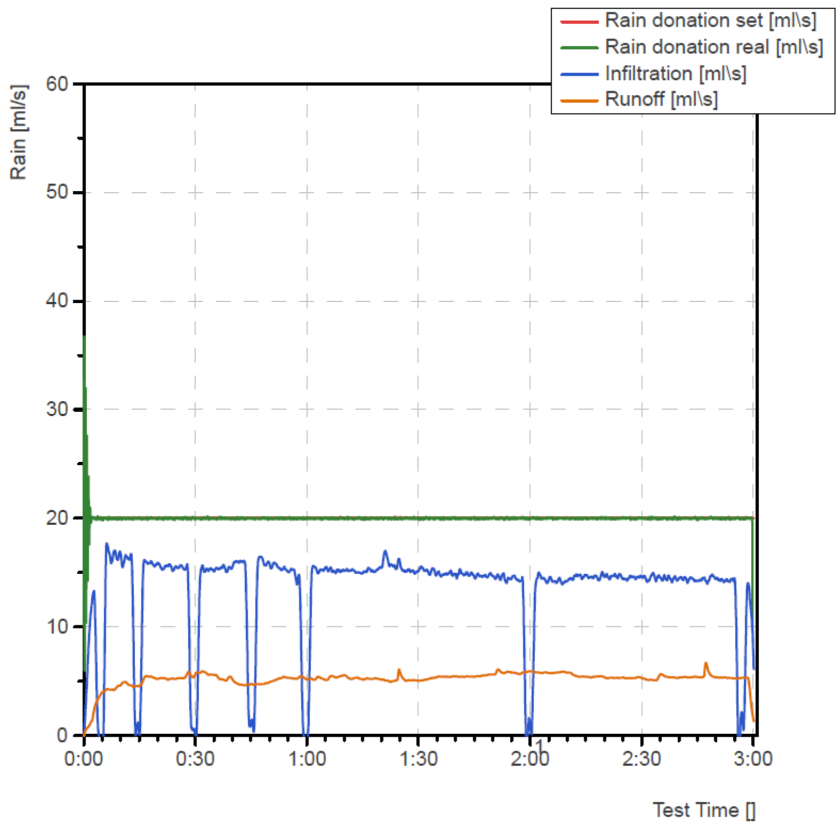

Figure 5. Example of test summary included for each experiment corresponding to test TD_CSL30y.