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## Assessment of permeable pavement clogging in the lab. Do we need new standards for it?

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### Abstract

In this paper we present the analysis of the clogging process of various types of permeable pavements using different sediment sources and methodologies at UDC and IKT laboratories. The work analyses the influence of the type of sediment used to study the performance of these types of urban drainage assets and discuss how the laboratory results can be used for long-term modelling of the clogging of permeable pavements.

### Highlights

- Permeable pavements reduce runoff but can lose effectiveness due to sediment clogging.
- There is a lack of consensus in testing methodologies for clogging assessment.
- Experimental studies performed at UDC and IKT reveal the need for unified testing procedures.

### Introduction

Permeable pavements have emerged as a solution to address stormwater management challenges in urban catchments by allowing rainwater to infiltrate into the ground, reducing runoff and helping to recharge groundwater aquifers, and mitigating the peak runoff during heavy rainfall events. This avoids, in both cases, overwhelming urban drainage systems and contributing to mitigation of water pollution. However, the long-term performance of permeable pavements can be affected by clogging problems caused by the accumulation of sediments accumulated during dry weather (Nolting *et al.*, 2005). Understanding the factors influencing the permeability reduction of the pavements during their service life, such as aging, pavement characteristics or pollution levels, is thus crucial for maintaining and optimising the long-term performance of permeable pavements in different urban contexts.

While field studies require long-term experimental campaigns on existing pavements, laboratory tests use accelerated methods with simulated rainfall to analyse the long-term hydraulic performance of permeable pavements, enabling relatively rapid testing for assessing and developing new and existing permeable solutions before its installation. However, there is no consensus in the literature or standards on the methodology to assess permeable pavements and a large variability is present in terms of testing size; the way to incorporate rainwater inflow; the load, characteristics, and particle

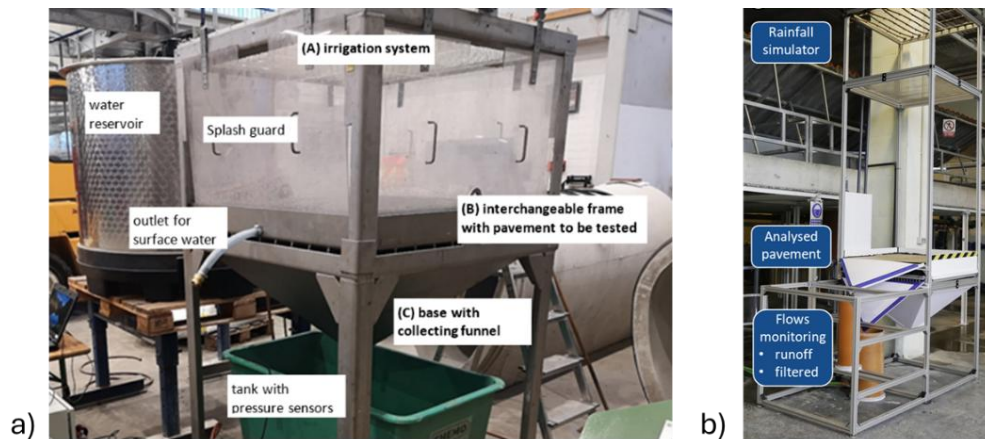
distribution of the material used to produce clogging; or the target variables of the tests and the methodologies to determine them. For example, pavement specimens range from small cores of a few centimetres (e.g. Haselbach, 2010) to slabs of 1 m<sup>2</sup> (e.g. DIBt test procedure 2022) or even full-scale 1:1 street reaches (e.g. Goya et al., 2025). This variability is also evident when studying the type of inflow used, with simulated runoff or rainfall inputs ranging from 20 to 400 mm/h and durations from a few minutes to several hours. The type of sediment from small synthetic sediments (e.g. Milisill dust in the DIBt procedure) to sediments collected in real environments (García-Haba et al., 2023) also shows a high variability.

This heterogeneity in experimental procedures compromises the comparability of results hindering joint progress or at least slowing it down. Moreover, this lack of consensus not only affects the scientific community but also creates uncertainty among manufacturers and authorities, who lack clear references when developing or selecting a permeable pavement. The absence of unified criteria can lead to reduced confidence in these systems, limiting their broad implementation and making it more difficult to optimize their design and maintenance.

In this context, the work developed comprises a comprehensive review and analysis of different methodologies to assess permeable pavement clogging using laboratory tests over 30 scientific studies and standards by the Universidade da Coruña -UDC - (Spain) and the IKT - Institute for Underground Research (Germany) in the framework of the Horizon 2020 project Co-UDlabs. Then, the most common methodologies were used in the lab to assess and discuss their potential application to practical or scientific case studies, considering different permeable pavement typologies and different sources of sediments such as real road dust sediment, standardized quartz powder or tyre dust.

## Methodology

Following the comprehensive review performed, two different facilities were used to assess the reliability and usefulness of different methodologies. First, The IKT test stand (Figure 1a) was designed following the German procedure DIBt (2022) and consists of three parts: a rainfall generator system placed above a flexible interchangeable frame of 1 m<sup>2</sup> in which tested pavements were installed. The rainfall simulator is based on an acrylic tray, in which a total of 625 stainless steel cannulas with an inner diameter of 0.9 mm enables uniform irrigation with variable rainfall discharge. The infiltrated water through the pavement and the runoff drained by a perimetral channel are measured by determining the volume in the reception tanks by a level sensor and a scale, respectively.



**Figure 1.:** a) IKT and b) UDCs test stands used for the assessment of the different methodologies to analyse permeable pavement long-term performance due to clogging.

Then, UDC stand (Figure 1b) is based on a dripper-based rainfall simulator of 1 m<sup>2</sup> with a metallic mesh that breaks and distributes raindrops producing uniform and realistic rainfall like in the large rainfall simulators available in CITEEC technological center at UDC (Naves *et al.* 2020). An impervious surface with a 2% slope was used to hold the permeable pavements tested. Filtered rainwater through the pavement and the runoff generated are laterally drained into separate circular tanks, where the level variation is measured with ultrasonic sensors for the estimation of water flows

Three different pavements were tested at these two facilities. At IKT, a 1 m<sup>2</sup> interlocking concrete block pavements (ICBP) with joints filled with 2 mm sand placed over a limestone chipping bedding layer. At UDC, a 1 m<sup>2</sup> interlocking pavement systems made up of porous concrete slabs over a geocell structure and an intermediate geotextile layer (DPS), and a 0.44 x 0.44 x 0.06 m<sup>3</sup> porous asphalt (PA). The clogging was assessed using 3 different sediment sources: (MD) Milisill W4 mineral dust,  $d_{50}=64 \mu\text{m}$ ,  $d_{\text{max}}=250 \mu\text{m}$ , density 2.65 g/cm<sup>3</sup>; (RD) Road dust collected from UDC parking lots with a realistic (non-uniform) PSD,  $d_{50}=282 \mu\text{m}$ ,  $d_{\text{max}}=1000 \mu\text{m}$ , density 2.93 g/cm<sup>3</sup>; (TD) Tyre dust  $d_{50}=64 \mu\text{m}$ ,  $d_{\text{max}}=200 \mu\text{m}$ , density 1.16 g/cm<sup>3</sup> (Figure 2). All materials tested at IKT with the ICBP following DIBt procedure. RDS material was used at UDC with the rest of pavement typologies and following the methodology in García-Haba *et al.* (2023). Constant and variable head permeameter and outflows monitoring have been also assessed as target values to characterize clogging evolution from a practical point of view.



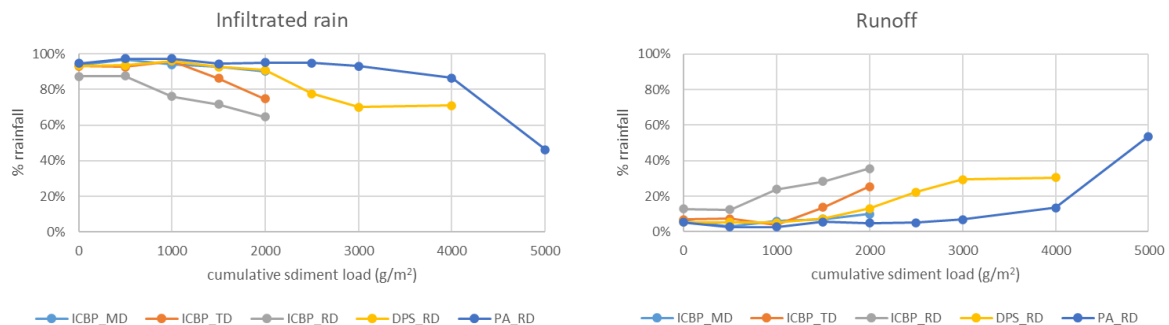
**Figure 2.:** Milisill W4 mineral dust (left), road dust sediments collected from UDC parking lots with a realistic (non-uniform) PSD (center) and plastic tyre dust at IKT test stand (right) during the experimental campaign on ICBP pavement.

## Results and discussion

The results presented in this paper focus on determining the hydraulic permeability and material retention of different types of pavements subjected to various pollutant sources, such as plastic dust

and particulate sediments with different PSDs. Figure 3 shows the evolution of the infiltrated and runoff volume percentages assessed in the three permeable pavements tested, with cumulative loads of the different clogging materials up to 5000 g/m<sup>2</sup>. Infiltration and runoff rates are normalized based on the rainfall intensities of 72.9 mm/h for IKT tests (ICBP tests) and 80 mm/h for UDC tests (DPS and PA tests).

As testing methodologies are different, the results obtained are clustered into the two facilities results making difficult as foreseen their comparison. At IKT tests, no significant differences in the averaged evolution of clogging with MD and RD were found. TD loads reduced the permeability of the ICBP at a higher degree. As the density of the TS is much smaller, more volume of dust is added to the pavement for the same mass forming aggregates and clogging the joints more quickly. At UDC tests, both pavements showed an important reduction of their permeability at about 3 - 4 kg/m<sup>2</sup> load. These results are in line with the comparison of different sediment granulometries and sources performed by García-Haba *et al.* (2023) with a porous asphalt slab (PA) following the same methodology.



**Figure 3.** Evolution of the infiltrated rainfall and runoff generated in the different permeable pavements (ICBP: interlocking concrete block pavement, DPS: dry paving system, PA: porous asphalt) with different cumulative sediment loads in g/m<sup>2</sup> and different sediment sources (MD:Milisill Dust, TD: Tyre Dust and RD:Road dust).

## Conclusions and future work

We have presented the initial results of a study that aims to analyse different methodologies to study the clogging process of permeable pavements. The results obtained in two laboratories using different methodologies highlight the need to advance in the development of a protocol to study clogging process of permeability pavement, to improve the management of these assets. The obtained results will help to calibrate predictive models for long-term clogging by providing harmonized empirical data and to identify key variables, which can be used to optimize pavement design and maintenance. Additionally, lab results allow for scenario analysis, helping to plan for different environmental conditions and urban development scenarios. These initial results also came up that monitoring outflows as recommended by DIBt procedure give only information for advance clogging status, so further work is being analysed by comparing flow monitoring results with other methodologies to assess intermediate states of clogging such as using constant or variable head permeameters.

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