

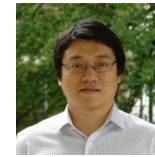
The development of a novel permeable pavement system based on Polyurethane binder

基于高性能聚氨酯(PUPP)海绵城市全透水路面关键技术研究

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- **Generation an environmentally friendly and climate-neutral infrastructure**
 - Reduction of greenhouse gases 减少温室气体
 - Reducing the sealed surfaces 减少硬化铺装
 - Reducing of the Heat Island Effect 降低热岛效应
 - Efficient usage of energy and raw materials 材料使用效率
- **Projects of the innovative pavement materials in ISAC 亚琛工大新材料项目**
 - **INNO-BOND: 2013-2015**

Development of new road construction materials and innovative manufacturing and installation methods 开发新的路面材料—聚氨酯
 - **INNO-PAVE: 2016-2018**

Basic research of polymer materials as well as innovative manufacturing and installation technologies for road surface layer systems 路面新材料摊铺技术
 - **Unsaturated pavement: 2016-2020**

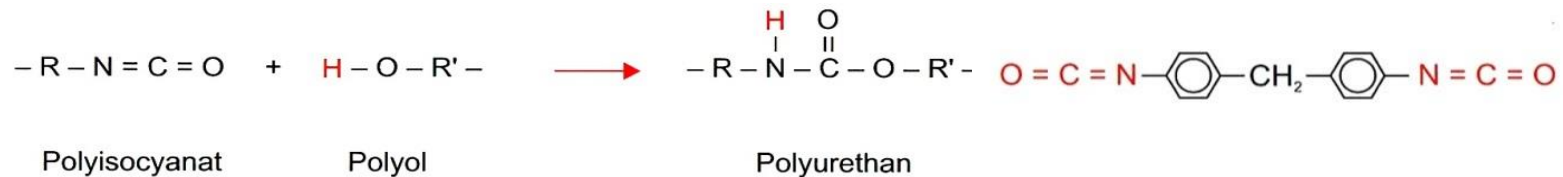
Hydro-mechanical interaction in permeable pavement structures in partially saturated conditions 透水路面劣化机理



Sponsors:



- Complete substitution of bitumen with sustainable, environmentally friendly binders
 - A Bio-Binder Polyurethane 一种路用生物聚氨酯
- A 2-component pavement used Polyurethane: 路用两组份聚氨酯粘结剂
 - From the reaction between Polyol and Isocyanat 由多元醇与异氰酸酯硬化反应



- Material properties can be adapted to the specific application (viscosity and elasticity)
 - Change in the polyurethane formulation
 - Modification by means of special additives

(通过调整两个组分的成分和配比、添加聚合物改性剂, 可以达到改变力学性质的目的弹性、粘性、流变学性质、强度);



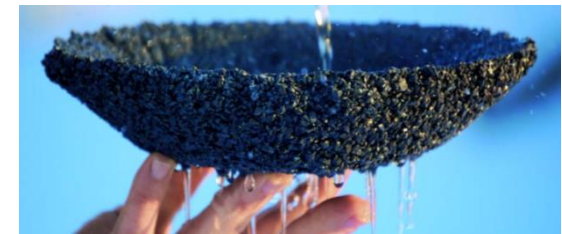
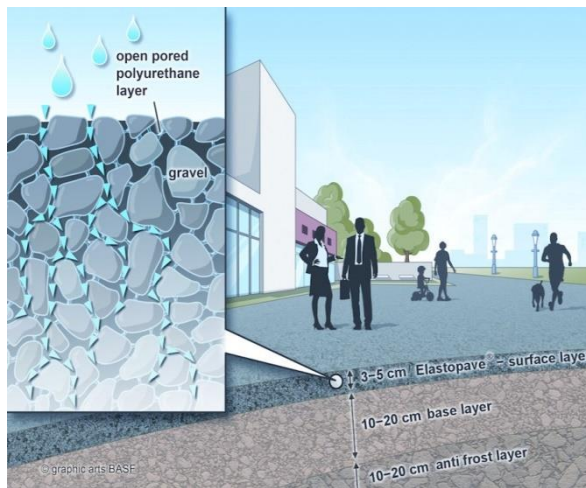
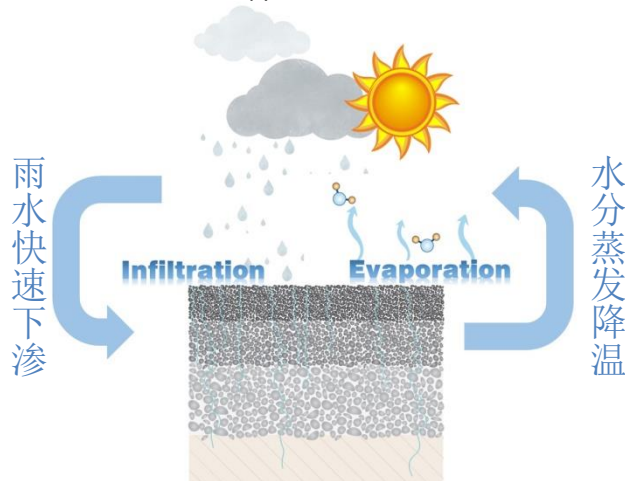
- Enhance the mechanical connection between aggregates
集料接触点的机械连接而构成的材料强度

- Higher material strength and performance 材料强度稳定性高
- Higher porosity and optimized pore geometrics 材料孔隙含量高

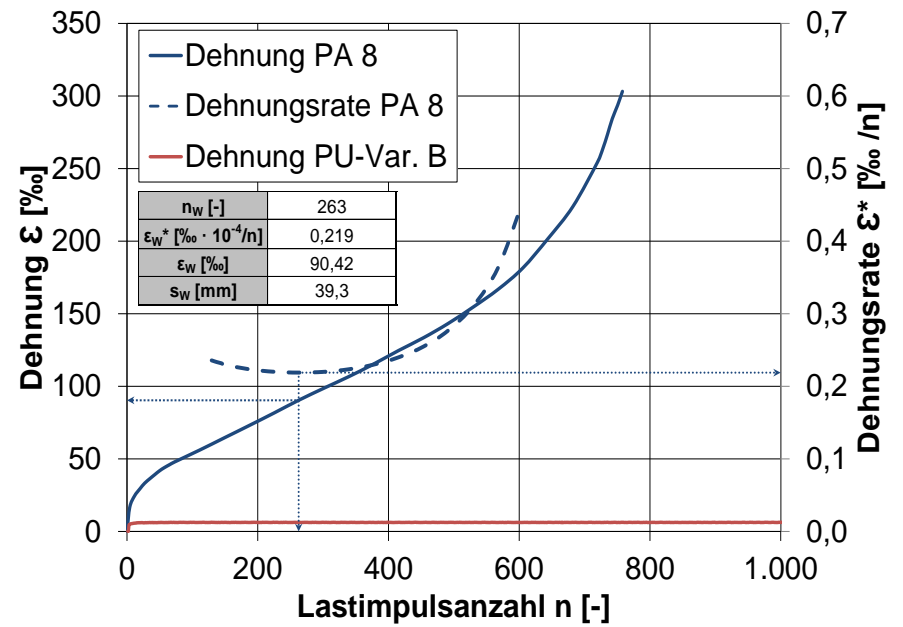
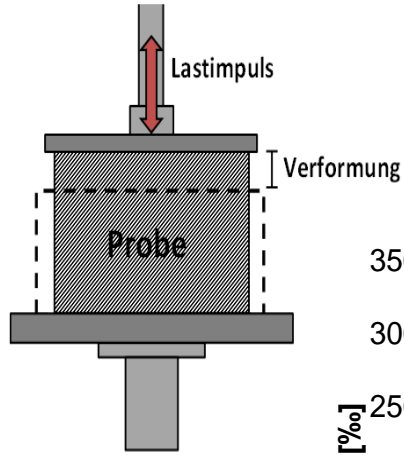
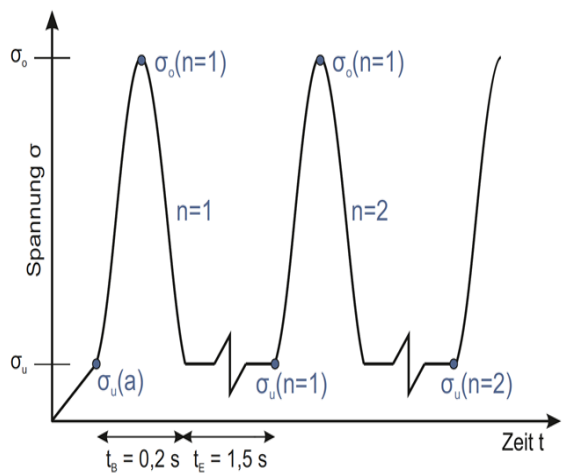
- The polyurethane based permeable pavement
基于聚氨酯设计的多孔隙透水路面

- Enhance the mechanical and functional performance of pavement, such as: permeability, noise reduction, cooling effect, energy harvesting, landscape design and environmental impact etc.

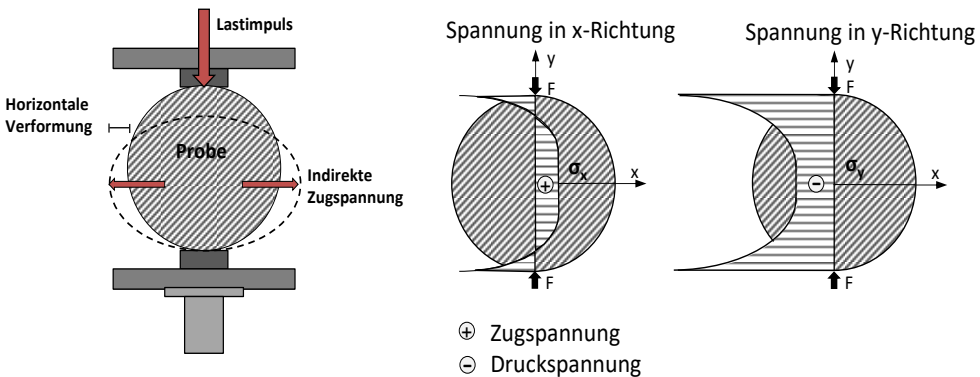
聚氨酯透水路面不仅力学强度高，且集透水、透气、降温、减噪、美观、环保等多功能性为一体



Dynamic compressive tests — 动态单轴压缩试验对比传统多孔沥青



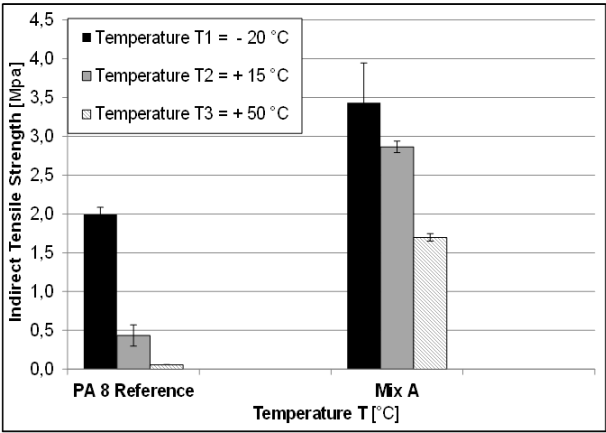
Indirect Tensile Strength Test (ITST) – 间接拉伸实验



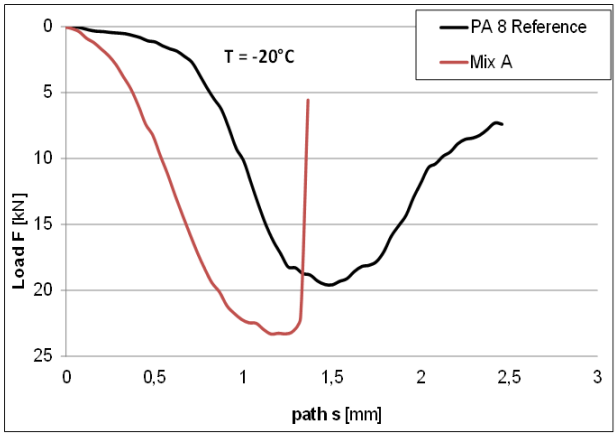
Experimental Parameters 实验参数:

- Reference standards 参照规范: TP Asphalt-StB, Teil 23
- Loading rate 加载速率: 50mm/min
- Temperature control 温度控制: -15°C; +15°C; +50°C

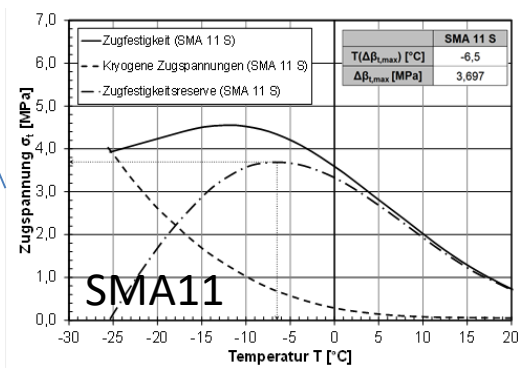
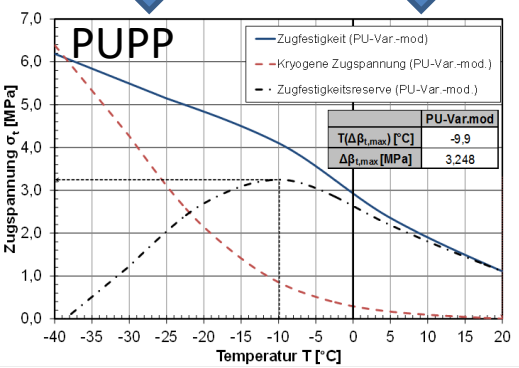
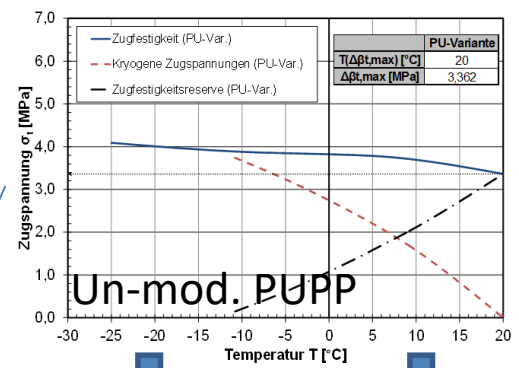
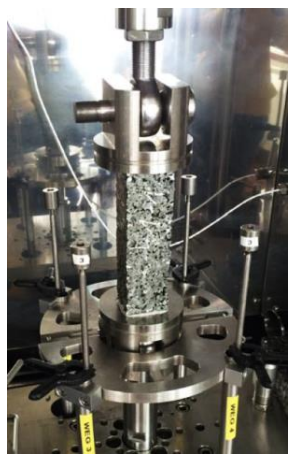
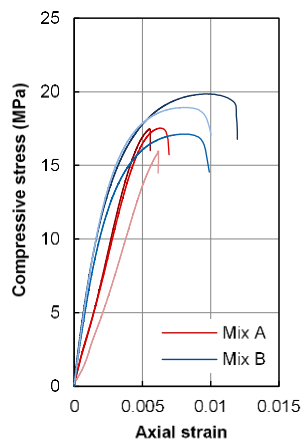
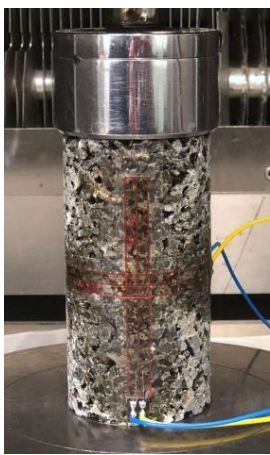
Comparison of indirect tensile strengths 间接拉伸强度对比



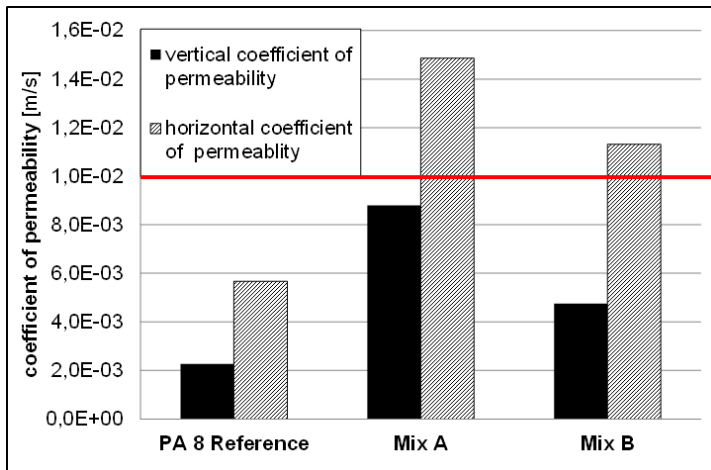
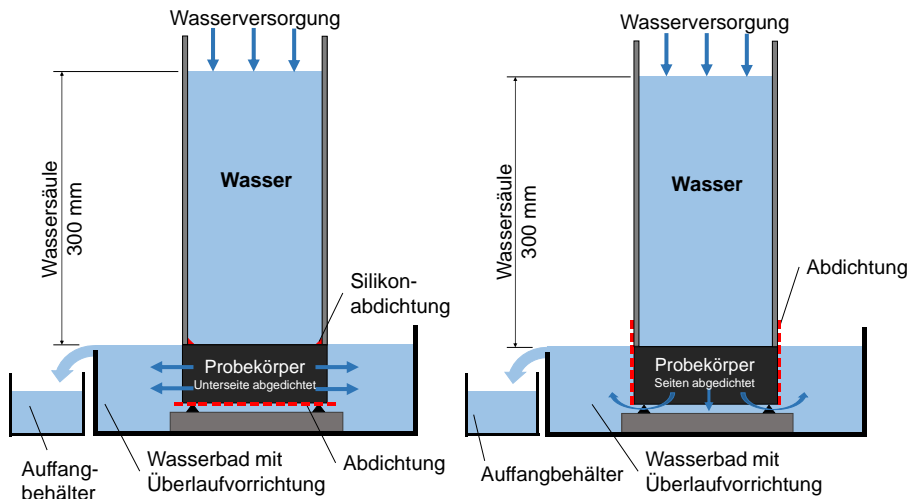
Comparison of the deformation process 变形能力对比



Cold temperature tensile tests – 低温收缩实验



Permeability tests 透水性能测试:



透水率参考标准DIN18130-1

k [m/s]	Bereich
unter 10^{-8}	sehr schwach durchlässig
10^{-8} bis 10^{-6}	schwach durchlässig
über 10^{-6} bis 10^{-4}	durchlässig
über 10^{-4} bis 10^{-2}	stark durchlässig
über 10^{-2}	sehr stark durchlässig

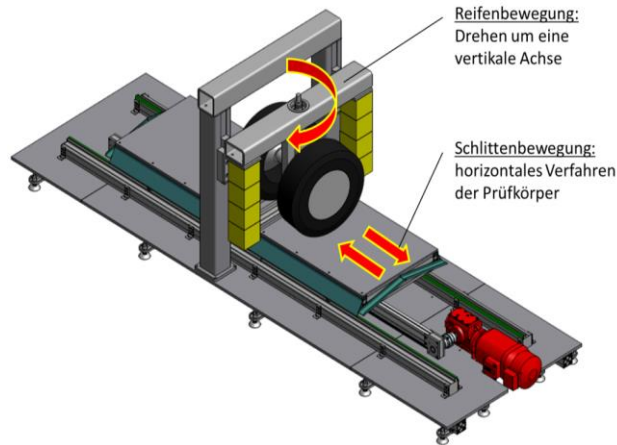


A U-shape Vertical Permeability Test



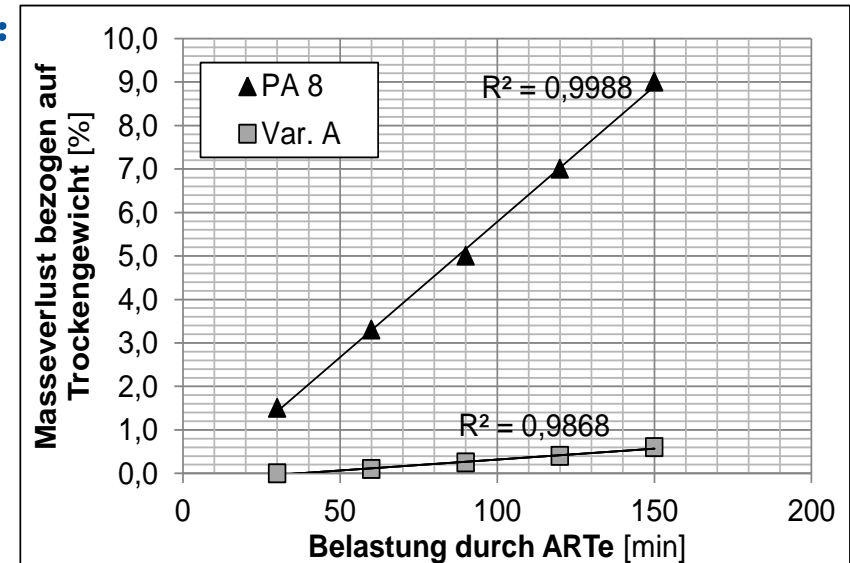
A horizontal permeability test

Skid resistance tests 抗滑/磨光性能测试:



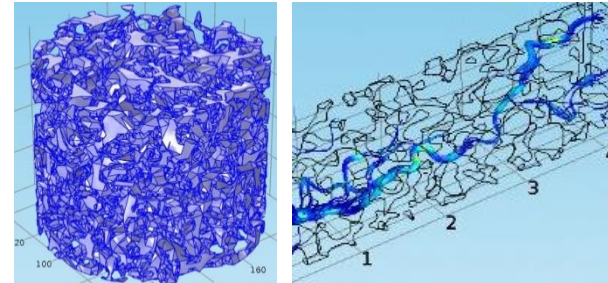
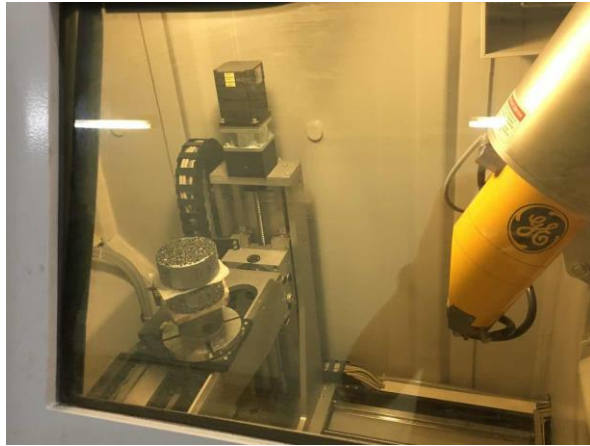
Aachener Raveling Tester (亚琛自主研发磨光机器)

Prüfparameter 实验参数	单位	数值
轮胎转速	U/min	41
试件滑动速度	m/s	0,3
载重量	kg	200
压力持续时间	min	30
负载数量	-	5
总磨光数	-	6150

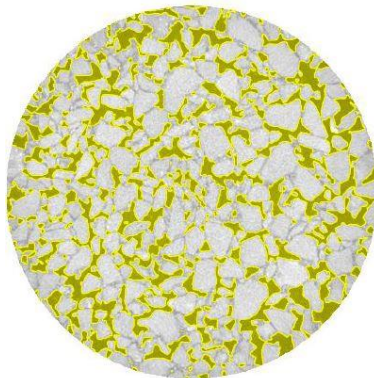


对比多孔沥青经过150分钟磨光后

The clogging effect evaluation 孔隙过滤/抗堵塞效率分析:



PUPP Pore characteristic and clogging analysis in FEM
聚氨酯细观孔隙结构与耐堵塞寿命分析
(Reference 参考: Research done in RWTH亚琛工大
德国国家科学基金项目研究内容)



Parameter	Porosity 孔隙率
Mixture A (0/8mm)	0.283
Mixture B (0/5mm)	0.289

在保证高强度力学性能下，有效孔隙率高达28%以上，抗堵塞效率是普通多孔沥青的四至五倍

Parkplatz auf einem Betriebsgelände
130 Stellplätze auf 3.500 m²
Vollständig versickerungsfähig
Einbau im teilmaschinellen Verfahren



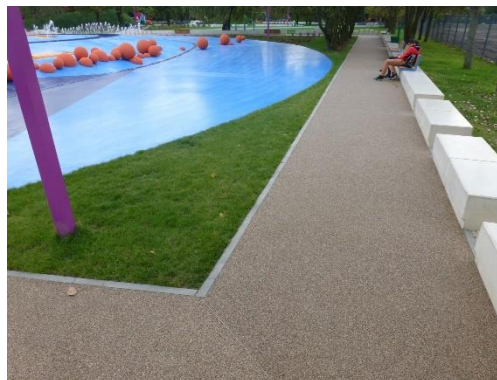
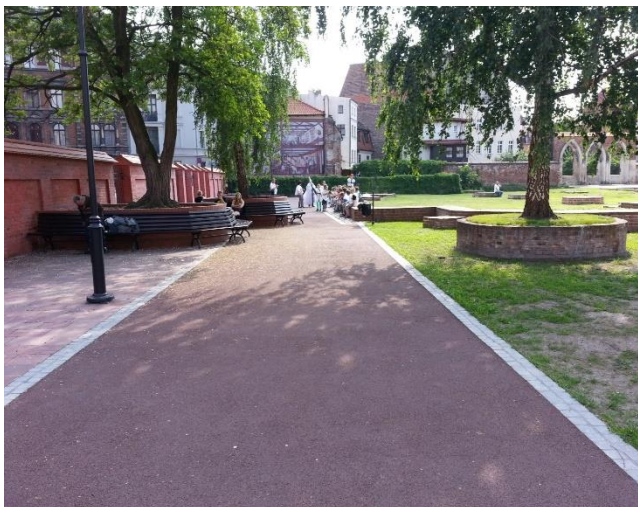
Quelle: BASF Polyurethanes GmbH



Parkplatz auf dem Betriebsgelände der BASF
130 Stellplätze auf 3.500 m²
Vollständig versickerungsfähig
Einbau im teilmaschinellen Verfahren



科隆动物园、生态示范小区、大众汽车工业园区、荷兰生态小镇等百余生态案例工程；



Application in China 中国成熟应用案例



Application in China 中国成熟应用案例



G20 杭州莫干山路改造



厦门海沧区中试药基地



福建省厦门市自贸区公园



昆明市政道路

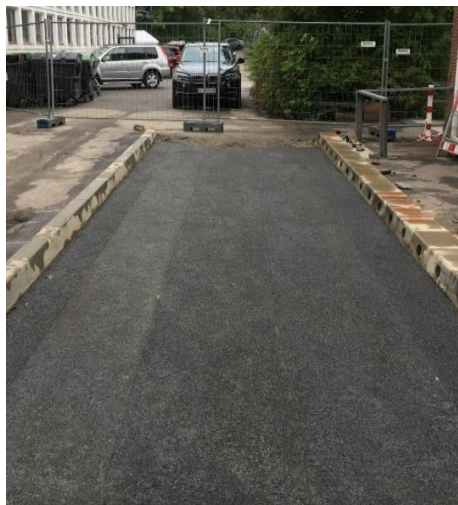
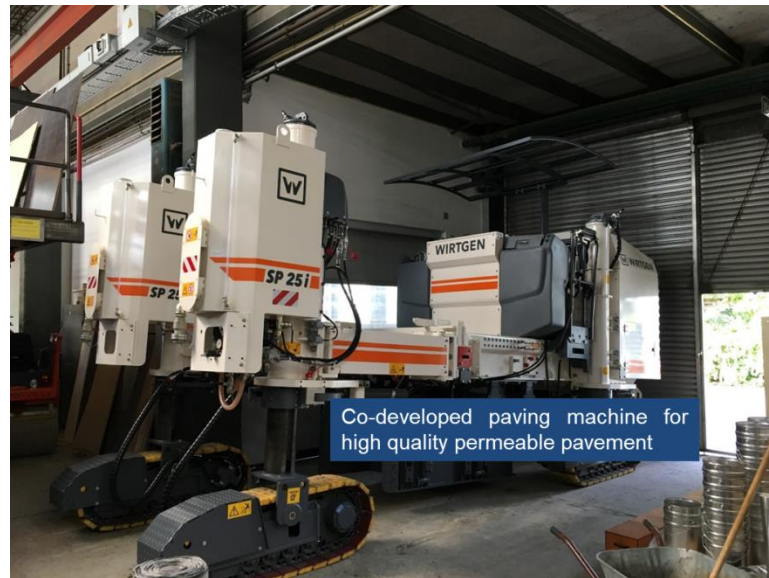
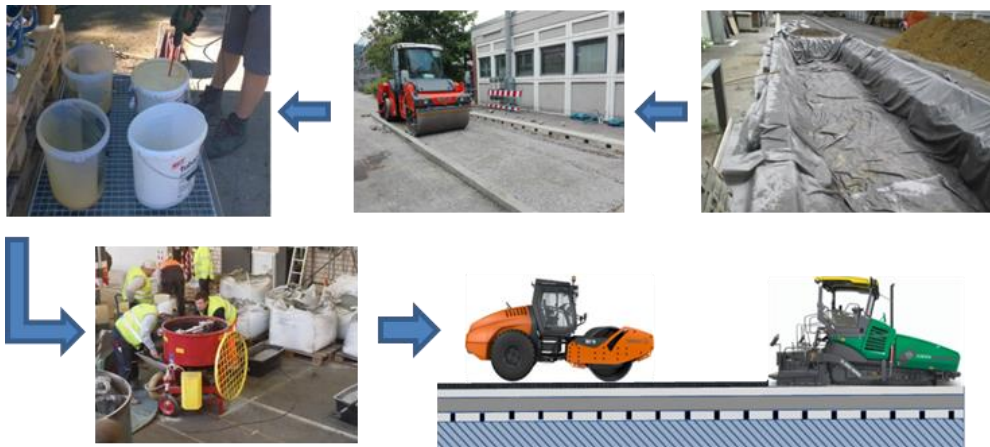


香榭丽都小区

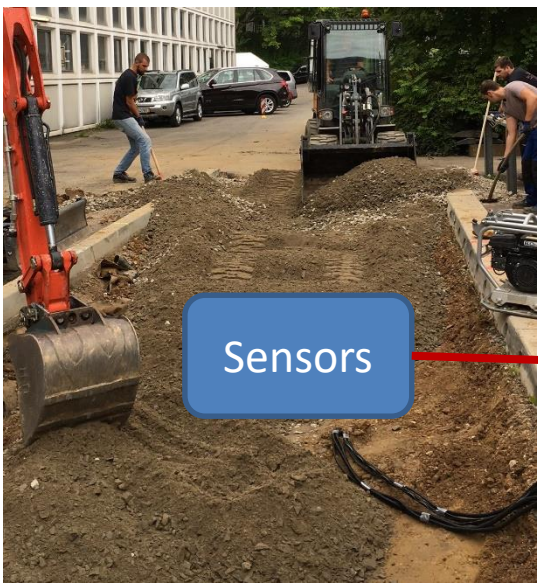


上海巴斯夫总部基地

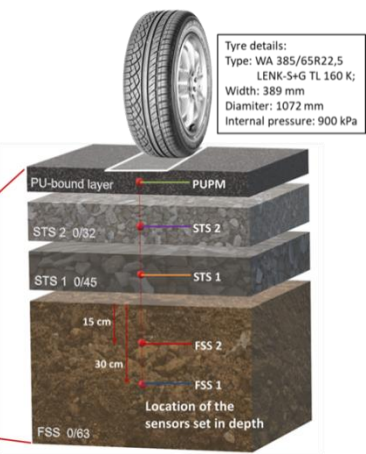
High-level pavement structures & Paving technology 快速摊铺技术研发



High-level pavement structures & Paving technology 路面结构设计 & 监控

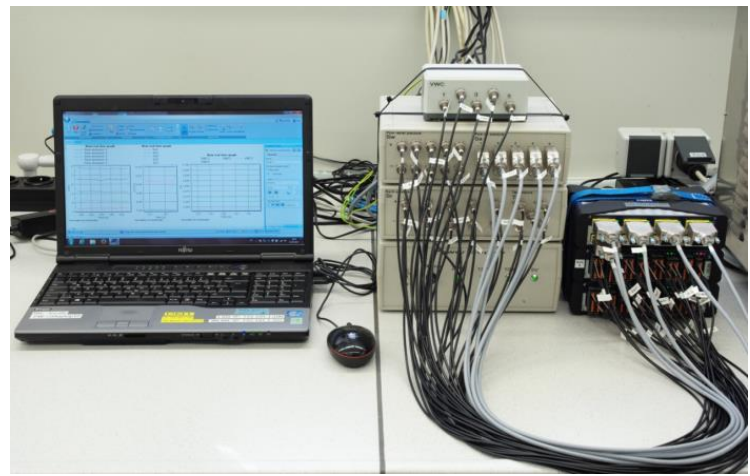
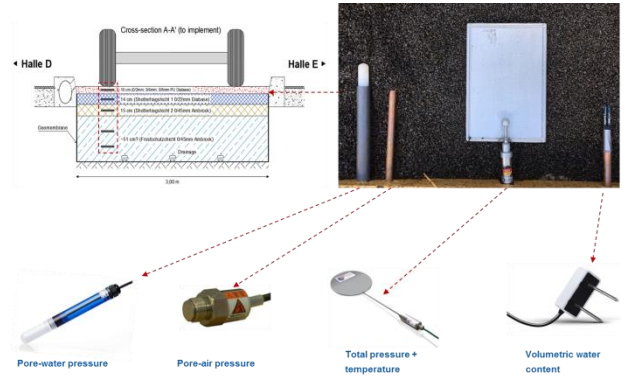


Sensors



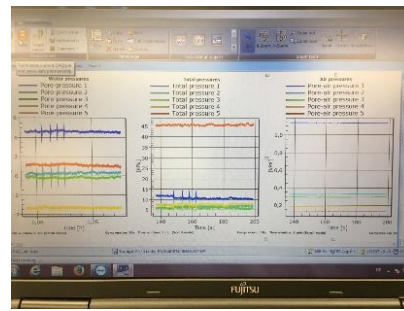
Tyre details:
 Type: WA 385/65R22,5
 LENK-S+G TL 160 K;
 Width: 389 mm
 Diameter: 1072 mm
 Internal pressure: 900 kPa

Monitoring system

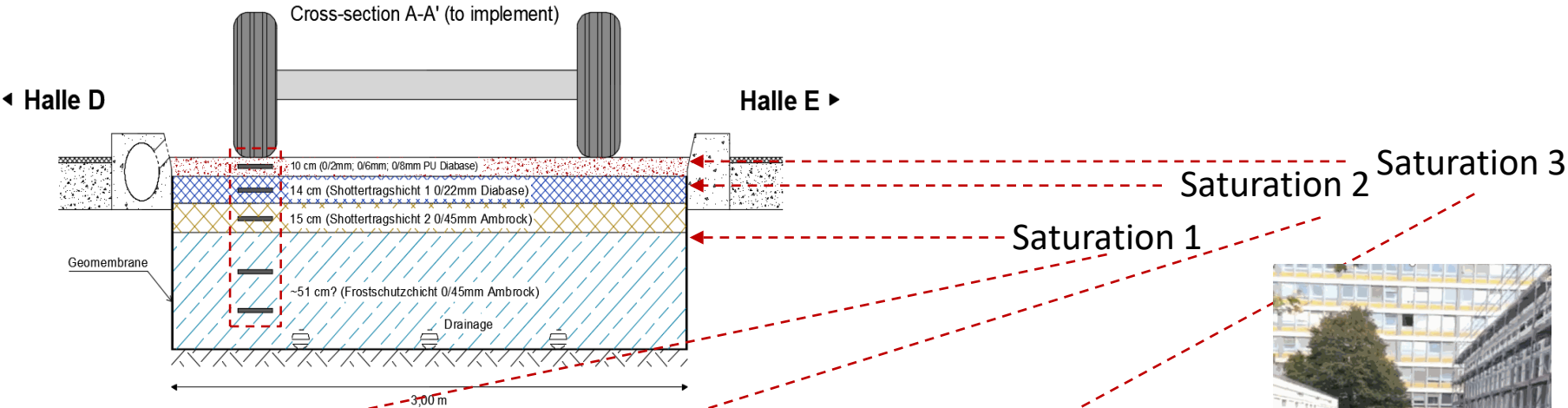


The initial structural parameters were assessed with Falling Weight Deflectometer (left) and 3D Ground Penetrating Radar (right) from the BAST.

FWD与探地雷达监测

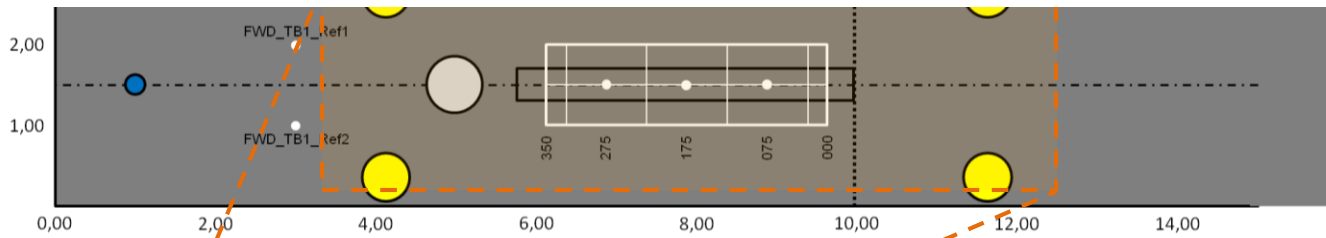


Hydro-mechanical interaction subjected to different saturation states 全透水结构水-力耦合作用在多饱和度状态下检验

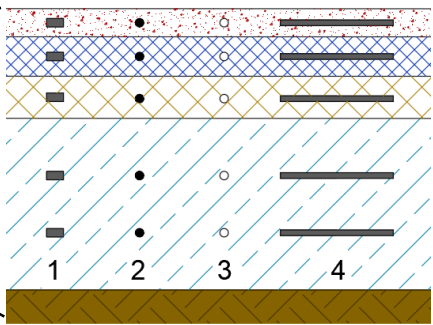
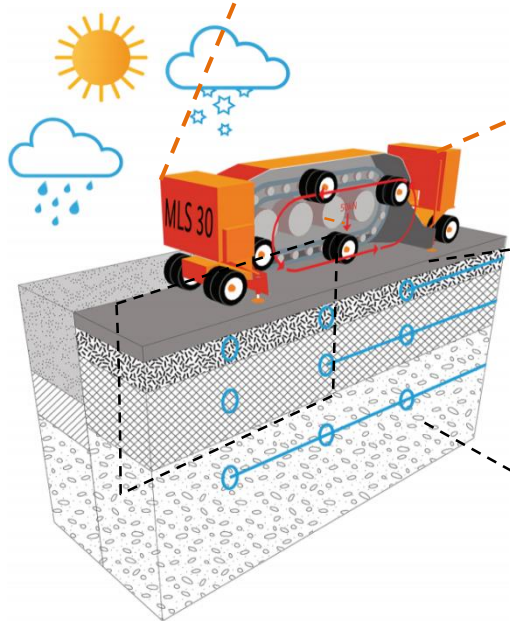






(Video)

Real-scale loading with APT and monitoring of the internal stresses at several water contents 多饱和状态下加速加载设备检验

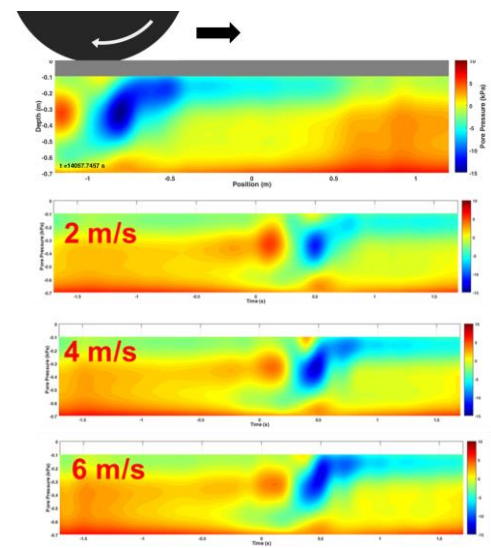
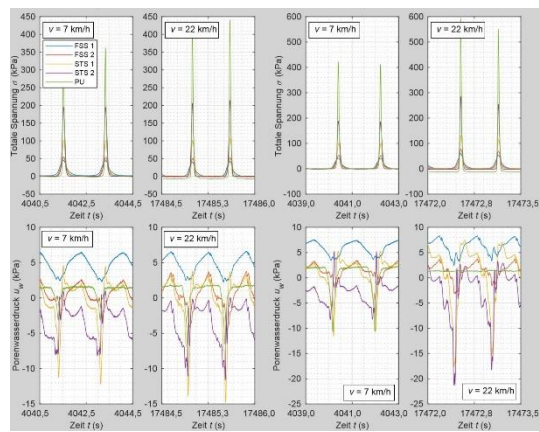


- Wasserzfluss
- Schacht
- Corner Jack
- FWD Punkt



- 1  Volumetric water content
- 2  Pore-water pressure
- 3  Pore-air pressure
- 4  Total pressure + temperature

Real-scale loading with APT and monitoring of the internal stresses at several water contents 多饱和状态下加速加载设备检验





(Shot by Lukas Renken,
2018-10-19, 9.00 am in
German Highway)

Thank you very much !

