Problem: The urban population continues to grow steadily on a global scale, which has so far been inevitably associated with an increase in road traffic. Furthermore, truck traffic is getting more intense in sync with GDP growth in the respective country or region. The resulting nitrogen oxide concentrations pose a major hazard to the health of the people who live and work in such urban agglomerations. At a large number of measuring points in cities, legal thresholds for pollutant concentrations, particularly nitrogen dioxide, continue to be exceeded despite the general downward trend in pollutant levels in Germany achieved thanks to a number of measures implemented in the past few years. This situation is not least due to the fact that the automotive industry has not delivered on its promise to develop engines with lower pollutant emissions. To overcome these challenges, a wide variety of actions are currently under discussion both in Germany and Europe, including the future expansion of electric mobility, low-emission engines, retrofitting diesel engines, and — in the very short term — imposing inner-city driving bans on certain vehicle categories. Yet our AirClean® technology provides another effective short-term option to reduce NO₂ concentrations in the air we breathe.

Our contribution to improving the situation: AirClean® concrete block pavements or asphalt road surfaces with AirClean® grit use the principle of photocatalysis to reduce airborne pollutant levels. For the first time in Germany, the City of Fulda has adopted and implemented a clean air action plan that also provides for the installation of pavers that reduce the concentration of nitrogen oxides.

<table>
<thead>
<tr>
<th>Installation of AirClean®</th>
<th>Project: Petersberger Strasse</th>
<th>Place: City of Fulda</th>
<th>Designed by: Fulda Municipality/Road and Transportation Department</th>
</tr>
</thead>
<tbody>
<tr>
<td>· Product: Thüringer Pflaster</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>· Colour: grey</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>· Area paved: 4,500 m²</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>· Completed in 2010</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Installation of AirClean®</th>
<th>Project: Am Hopfengarten</th>
<th>Place: City of Fulda</th>
<th>Designed by: Fulda Municipality/Road and Transportation Department</th>
</tr>
</thead>
<tbody>
<tr>
<td>· Product: Thüringer Pflaster</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>· Colour: grey</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>· Area paved: 1,200 m²</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>· Completed in 2010</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Various series of in-house tests as well as experiments conducted at the Fraunhofer Institute proved the effectiveness of this solution. Do not hesitate to contact us for detailed information.
Installation of AirClean®
- Products: Rima 21/21/8 and Tavolo 18/15.3/8
- Colour: grey
- Area paved: 640 m²
- Completed in 2010

Project: Goetheplatz
Place: Bad Salzungen
Designed by: Bad Salzungen Mukipatuty and Tiefbautechnisches Büro Werra GmbH, Bad Salzungen

Sunlight activates the photocatalyst (i.e. titanium dioxide) to trigger a rapid chemical reaction in a photocatalytic process. TiO₂ is a component of the concrete recipe and acts as a photocatalyst on the surface of the paving stone.

Installation of AirClean®
- Products: Primavera VS4.8, VS5 MAXX
- Colours: light grey, dark grey and grey
- Area paved: 6,000 m²
- Completed in 2012

Project: Sandershäuser Berg industrial estate
Place: Niestetal
Designed by: Oppermann GmbH, Vellmar

Whether you plan to complete a major project or just a small square: Any of these can reduce the concentration of airborne nitrogen oxides and significantly enhance quality of life.

Photocatalysis mechanism of action: The so-called catalyst is the most important component of the required chemical reaction. More specifically, we use a specially modified titanium dioxide (TiO₂) for this purpose. Furthermore, the TiO₂ molecules need to be exposed to sunlight. NO or NO₂ molecules (collectively referred to as NOₓ) are degraded as soon as they hit the TiO₂ surface, mainly into NO₃ (nitrate) and O₂ (oxygen) as well as OH molecules.

Initially, the nitrate remains on the surface; it is subsequently dissolved and washed off by stormwater. For urban roads, we can safely assume that the dissolved nitrate is discharged into the sewer system together with the stormwater. It then arrives at a water treatment plant, where the nitrate is removed in a cleaning process so that it can no longer create an additional burden on the groundwater.

TiO₂, the photocatalyst, is permanently bound to the concrete matrix, but its chemical composition remains the same. Titanium dioxide does not get depleted but remains unchanged during the chemical reaction that reduces pollutant concentration.
Laboratory tests: Experiments conducted by the Fraunhofer Institute for Molecular Biology and Applied Ecology showed that the chemical reaction of converting NOx also occurs when vehicle exhaust gases flow over the AirClean® pavement. The measuring set-up used for this test was based on an internationally applicable standard; it provides the option of comparing the photocatalytic activity of AirClean® pavers with various surface textures and colours.

Our product development process was supported by the German Federal Environmental Foundation (DBU).

Under identical ambient conditions, the NOx reduction rate achieved by AirClean® photocatalysis was measured at a height of three metres and directly compared with the performance of a reference paver without photocatalytic activity. AirClean® was tested both in a series extending over several months on a representative testing ground and in an urban environment under the supervision of the Fraunhofer Institute.

The individual series of tests led to impressive results. This outcome was also supported by a comprehensive report issued by the Fraunhofer Institute.

Yet any comparison must be taken with the proverbial pinch of salt because the thresholds stipulated by currently applicable legislation refer to the amount of airborne NOx, rather than using NO as a test gas to measure photocatalytic activity at the laboratory in accordance with the generally applied ISO 22197-1 standard. This situation alone makes direct comparability impossible.

Canyon test: This is why we complemented our series of laboratory tests by measuring NOx and NO reduction rates under realistic conditions at our street canyon testing ground. These tests were conducted jointly with the renowned Fraunhofer Institute for Molecular Biology and Applied Ecology and enabled derivation of the reduction rate that can realistically be achieved in the field.
Our offering:
Versatility on a nationwide scale. Possible uses of this specially designed, photocatalytically active paver go far beyond individual pavement designs and encompass virtually all concrete products, resulting in a varied selection of styles, colours and sizes.

Areas of use:
From small areas with a big impact to major projects that put the environment to the fore – the possible applications of AirClean® are just as versatile as the product range. As a matter of course, AirClean® is the perfect fit for major projects such as railway stations, heavily frequented traffic areas and parking facilities. Even more importantly, using AirClean® in urban areas where the major share of pollutants is generated helps preserve a vibrant and healthy living environment. Yet the same holds true for any endeavour to improve quality of life in cities or to enhance the appeal of a health resort. For any of these applications, the photocatalytically active AirClean® paver is the perfect solution when it comes to protecting and preserving our environment.

A long-term field test was performed at a height of three metres under variable wind and light exposure whilst average light intensities were 30% lower than the annual regional average due to shading. During the daytime measurement period, this test showed reduction rates of 18% and 29% for NO2 and NO, respectively. In still air, NO, reduction rates even went up to 70% (minute values). Under the conditions prevailing in the field test, AirClean® achieved an annual NO, reduction rate of 25% at a height of three metres when exposed to average light intensities typical of Central Europe (in the street canyon under daylight exposure).

The Fraunhofer Institute report is available if you are interested in learning more about the test results — do not hesitate to order it today. Likewise, we would be pleased to welcome you to our testing ground, so just come along and see for yourself.

Installation of AirClean®
- Product: Marktplaster
- Colour: porphyry
- Area paved: 350 m²
- Completed in 2010
Project: Petersberg townhall
Place: Community of Petersberg
Designed by: Community of Petersberg

Installation of AirClean®
- Products: Primacon® V55 37.5/37.5/12, V55 37.5/25/12, Thuringian pavers 30/30/8, gutter pavers 16/16/10
- Colour: grey
- Area paved: 3,000 m²
- Completed in 2008
Project: Strasse des Friedens/Gothoer Platz
Place: State Capital of Erfurt
Designed by: Erfurt Public Works and Transportation Department and Ercosplan, Hoch- und Tiefbauplanung, Erfurt

Real-life test series

NO2 concentration in μg/m³
0 50 100 150 200 250 300 350

NO2 comparison AirClean® vs Tegula (10 Nov 2009, 3 m above ground)
**AirClean® road grit**

... a completely new option to reduce airborne pollutant levels.

Application of the above-described AirClean® concrete paver technology results in a significant, measurable reduction in NOx concentrations — even under real-life conditions in an urban setting. However, the reduction potential of this technology can be utilised only to a limited extent when applying it exclusively to narrow footpath areas extending along main roads.

This is why we developed a pavement suitable for installation on main roads so as to reduce pollutant concentrations right at the emission source.

This new type of pavement is essentially composed of a synthetic crushed stone material made from concrete, which contains titanium dioxide (TiO₂), as also used for AirClean® pavers. A specially designed installation technique is applied to spread and roll this synthetic material directly into the new asphalt top course.

The embedded titanium dioxide lends photocatalytic properties to the grains (or chippings) adhering to the asphalt surface, and thus enables them to degrade harmful airborne NO and NO₂, according to the principle of photocatalysis outlined above.

Although this endeavour may appear simple at first glance, its implementation required a large amount of development work to design a construction material with reliable performance characteristics.

**Performance characteristics of AirClean® road grit**

AirClean® road grit is a synthetic crushed stone material with photocatalytic properties designed for use on asphalt. It meets all requirements of the EN 13043 standard governing aggregates for bituminous mixtures, as well as those of the German TL Gestein StB 04 (see table). You can thus be absolutely sure that this innovative construction material is in full compliance with the rules and specifications for the construction of asphalt road pavements.

<table>
<thead>
<tr>
<th>No.</th>
<th>Parameter</th>
<th>Symbol</th>
<th>Unit</th>
<th>Value</th>
<th>Standard/specifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Particle size distribution</td>
<td>G</td>
<td></td>
<td>G,90/15</td>
<td></td>
</tr>
<tr>
<td>2.a</td>
<td>Particle shape (shape index)</td>
<td>SI</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.b</td>
<td>Particle shape (flakiness index)</td>
<td>FL</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3.</td>
<td>Fines ratio</td>
<td>f</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4.</td>
<td>Quality of fines</td>
<td>MB</td>
<td></td>
<td></td>
<td>NPD</td>
</tr>
<tr>
<td>5.</td>
<td>Dry particle bulk density</td>
<td>kg/dm³</td>
<td></td>
<td>2.5 - 2.7</td>
<td></td>
</tr>
<tr>
<td>6.</td>
<td>Water absorption</td>
<td>m.-%</td>
<td></td>
<td>&gt; 0.5</td>
<td></td>
</tr>
<tr>
<td>7.a</td>
<td>Crushing resistance</td>
<td>SZ</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7.b</td>
<td>Crushing resistance</td>
<td>LA</td>
<td></td>
<td></td>
<td>NPD</td>
</tr>
<tr>
<td>8.</td>
<td>Polished stone value</td>
<td>PSV</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>9.</td>
<td>Abrasion resistance</td>
<td>AAV</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10.</td>
<td>Wear resistance</td>
<td>M</td>
<td></td>
<td></td>
<td>NPD</td>
</tr>
<tr>
<td>11.</td>
<td>Affinity to bituminous binders</td>
<td>M</td>
<td></td>
<td>60% (after 24 h)</td>
<td>NPD</td>
</tr>
<tr>
<td>12.</td>
<td>Resistance to heat impact</td>
<td>m.-%</td>
<td></td>
<td></td>
<td>NPD</td>
</tr>
<tr>
<td>13.</td>
<td>Weathering resistance</td>
<td>SB</td>
<td></td>
<td></td>
<td>NPD</td>
</tr>
<tr>
<td>14.</td>
<td>Freeze/thaw/de-icing salt resistance (1% NaCl)</td>
<td>F</td>
<td>m.-%</td>
<td>0.05</td>
<td>NPD</td>
</tr>
</tbody>
</table>

NPD = No Performance Determined

**Characteristics of AirClean® grit (synthetic crushed stone for use on asphalt)**
Proven effectiveness

Like in the case of the photocatalytic AirClean® pavers, we used our canyon testing ground to get a first impression of the pollutant-reducing effect of AirClean® grit. For this purpose, we installed an asphalt pavement that included areas with and without the material. We then carried out measurements to compare their performance.

The outcomes fully met our expectations, as shown in the diagrams below:

But we did not stop at this point because we wanted to arrive at a holistic assessment of this new construction method whilst also investigating options to continuously enhance its effectiveness. This is why we initiated and conducted a comprehensive research project funded by the German government under the HighTechMatBau programme. Its primary objective was to develop a multi-functional asphalt road pavement.

Research project:

Na HiT As
Sustainable High-Tech Asphalt

Objective: To design a multi-functional asphalt road pavement

- photocatalytic properties = pollutant reduction
- installation/monitoring techniques = innovative installation method
- methods to retain noise-mitigating properties = sustainability
- noise-mitigating texture = noise mitigation

Project results will be finalised by the end of 2018 and published in the related research report. Preliminary reports are already available in the download section of our website. Since mid-2018, we have been able to install photocatalytically active asphalt pavements jointly with our research partners. Do not hesitate to get in touch for further information regarding your project ideas.

Funded by the Federal Ministry of Education and Research (BMBF)/HighTechMatBau:
Production sites

Please note that the shades appearing on figures or photographs are indicative only and permit only limited conclusions as regards true colour and design.

Our products are manufactured with premium mineral aggregates that are subject to natural variations. The appearance of paved surfaces may change over time owing to continuous use and weathering.

Sales through:

Please note that the shades appearing on figures or photographs are indicative only and permit only limited conclusions as regards true colour and design.

Our products are manufactured with premium mineral aggregates that are subject to natural variations. The appearance of paved surfaces may change over time owing to continuous use and weathering.

Sales through:

Please note that the shades appearing on figures or photographs are indicative only and permit only limited conclusions as regards true colour and design.

Our products are manufactured with premium mineral aggregates that are subject to natural variations. The appearance of paved surfaces may change over time owing to continuous use and weathering.

Sales through:

Please note that the shades appearing on figures or photographs are indicative only and permit only limited conclusions as regards true colour and design.

Our products are manufactured with premium mineral aggregates that are subject to natural variations. The appearance of paved surfaces may change over time owing to continuous use and weathering.

Sales through:

Please note that the shades appearing on figures or photographs are indicative only and permit only limited conclusions as regards true colour and design.

Our products are manufactured with premium mineral aggregates that are subject to natural variations. The appearance of paved surfaces may change over time owing to continuous use and weathering.

Sales through:

Please note that the shades appearing on figures or photographs are indicative only and permit only limited conclusions as regards true colour and design.

Our products are manufactured with premium mineral aggregates that are subject to natural variations. The appearance of paved surfaces may change over time owing to continuous use and weathering.

Sales through:

Please note that the shades appearing on figures or photographs are indicative only and permit only limited conclusions as regards true colour and design.

Our products are manufactured with premium mineral aggregates that are subject to natural variations. The appearance of paved surfaces may change over time owing to continuous use and weathering.

Sales through:

Please note that the shades appearing on figures or photographs are indicative only and permit only limited conclusions as regards true colour and design.

Our products are manufactured with premium mineral aggregates that are subject to natural variations. The appearance of paved surfaces may change over time owing to continuous use and weathering.

Sales through:

Please note that the shades appearing on figures or photographs are indicative only and permit only limited conclusions as regards true colour and design.

Our products are manufactured with premium mineral aggregates that are subject to natural variations. The appearance of paved surfaces may change over time owing to continuous use and weathering.

Sales through:

Please note that the shades appearing on figures or photographs are indicative only and permit only limited conclusions as regards true colour and design.

Our products are manufactured with premium mineral aggregates that are subject to natural variations. The appearance of paved surfaces may change over time owing to continuous use and weathering.

Sales through: