International Sustainable Pavements Workshop

7-9 January 2010, AIRLIE CENTER, USA

Innovative Photocatalytic Pavements

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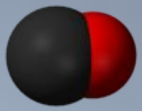
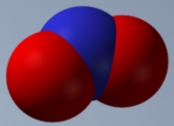
PRINCIPAL POLLUTANTS

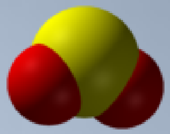
- Carbon Monoxide (CO)



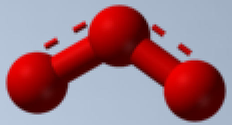
- Nitrogen Oxides (No_x)



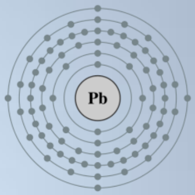
- Sulfur Dioxide (SO_2)



- Ozone (O_3)



- Particulate Matter (PM10, PM2.5)
- Lead (Pb)



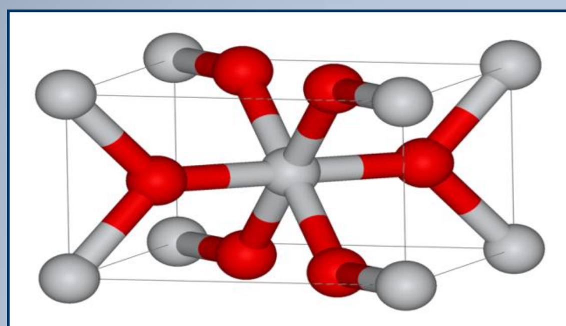
World Health Organization (WHO) research underlined that pollution is responsible for **100.000 deaths** each year in the European area

Titanium Dioxide

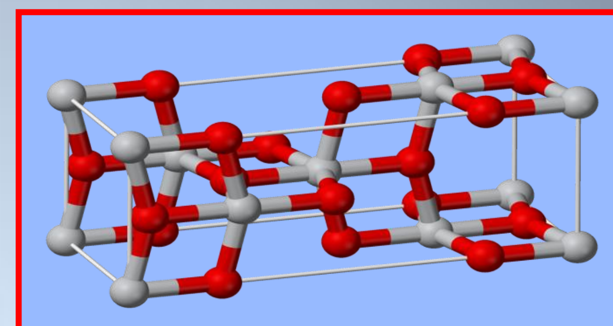
Depollution is the removal of contaminants and impurities from environment

The newest tool for achieving depollution is a **PHOTOCATALYST**

Titanium dioxide (TiO2), a white pigment, is the primary catalytic ingredient



Crystalline structure RUTILE



Crystalline structure ANATASE

Many variables influence this ability, especially the **grains dimension and the presence of impurities**. TiO_2 normally used has **nanoparticles** with a great specific surface (area to volume ratio) and diameter inferior to 100 nm

BIOLOGICALLY INERT, TiO_2 IS USED

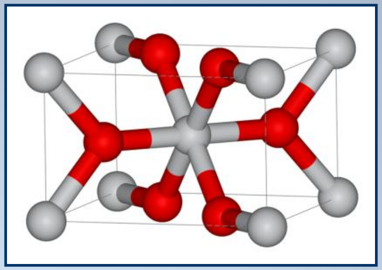
- for water and air **purification**
- for **medical use**
- as **pigments** in foodstuffs, paints, ceramics, cosmetics or pharmacology
- as **a corrosion resistant coating**, **self-cleaning** coatings and **anti-foggy**

- in **solar cells** for the production of hydrogen and electric energy, in **electronic devices and as gas sensor**

Photocatalytic Process

In presence of **sunlight** and **air** Titanium Dioxide produces a significant **acceleration of natural chemical reactions** reducing pollutants into inert elements

PHOTO CATALYST



LESS DANGEROUS / INERT ELEMENTS

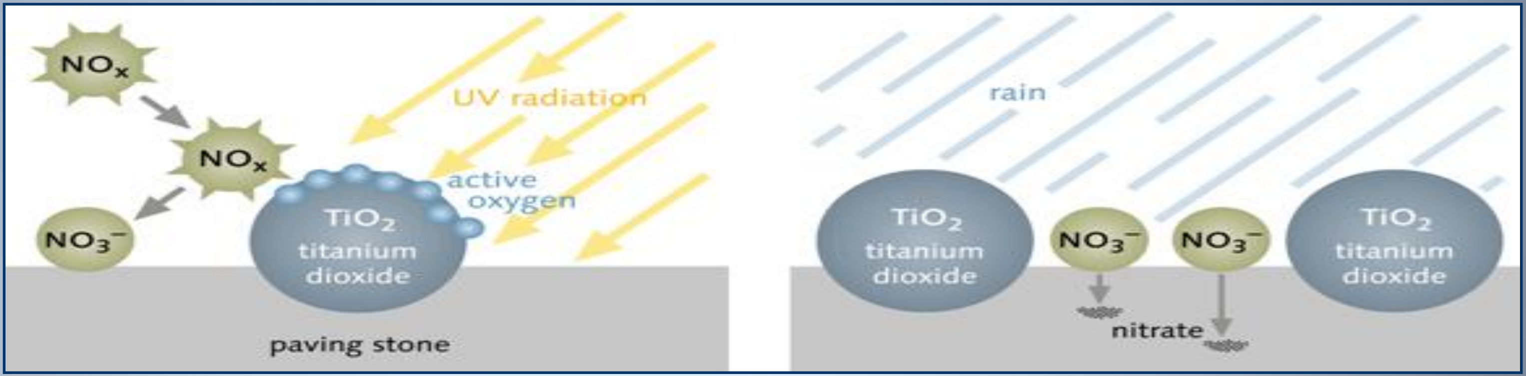
The result is a reduction of pollutants concentrations in the atmosphere (VOC, NOx, SOx)

The pollution reduction is proportional to the extent of the photocatalytic surface, treated with titanium dioxide, exposed to sunlight and air

Photocatalytic Process

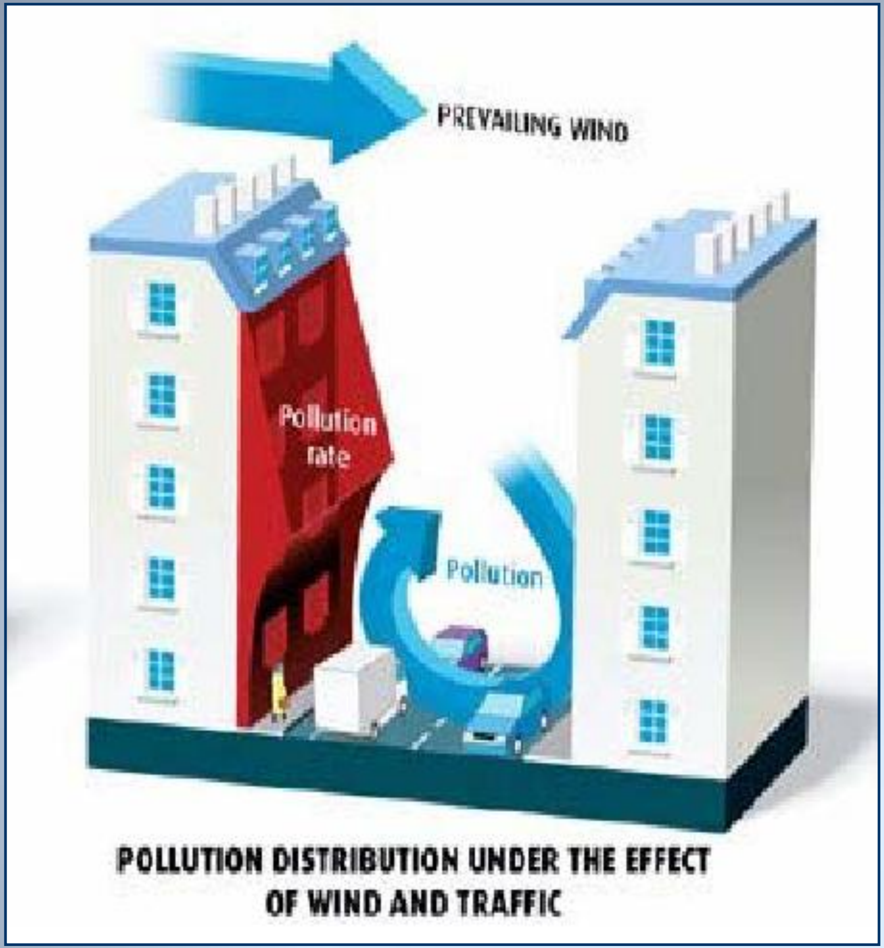
Nitrogen Oxides (NO, NO_2) are turned into raw material, washed away by water without a relevant pollution action, according to the photocatalytic oxidation mechanism

$$NO + HO_2\cdot \rightarrow HO\cdot + NO_2$$
$$NO_2 + HO\cdot \rightarrow HNO_3 \rightarrow NO_3^-$$



PHOTOCATALYTIC CONSTRUCTION MATERIALS

Titanium dioxide can be contained in the material or can be applied on its surface



Italian Applications

1. Introduction
2. European situation
3. Titanium Dioxide
4. Photocatalytic Process
5. Italian Applications
6. Photocatalytic Road Pavements:
   - Photocatalytic Cement Blocks Pavements
   - Photocatalytic Pavements Combining Asphalt and Cement Mortars
   - Bituminous Pavement Sprayed with Photocatalyitic Paint/Resin
7. Testing Protocol & Laboratory Test
8. Conclusion

CHARACTERISTICS

The photocatalytic products for asphalt concrete surfaces must be able to:

- decrease the **concentration** of atmospheric **pollutants** in the air
- guarantee the **adhesion** between wheels and pavements (road-safety)
- maintain the **functional and mechanical characteristics** of original pavements (for example: permeability, colour and bearing capacity)

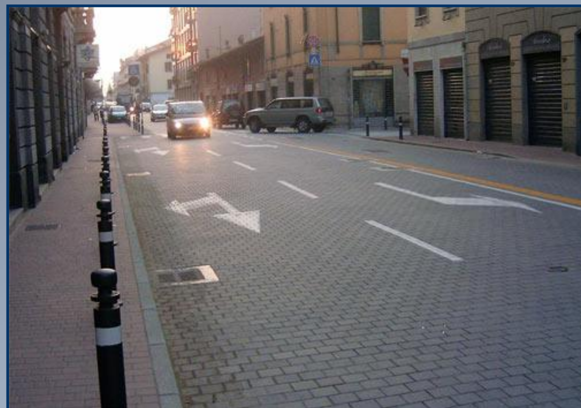
REQUIREMENTS

- No direct contact between photocatalyst (titanium dioxide) and binder (bitumen) because the photocatalyst causes an accelerate oxidation of the bitumen which is an organic binder

- An inorganic sublayer between bitumen and TiO2 is required

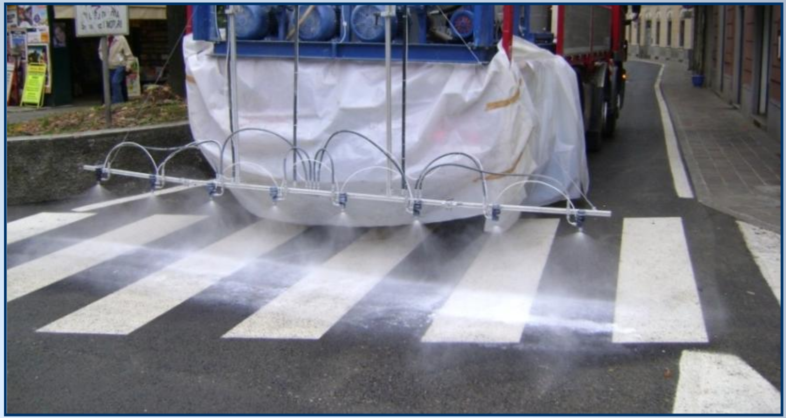
Photocatalytic Road Pavements

POSSIBLE TECHNIQUES



Photocatalytic cement blocks pavements

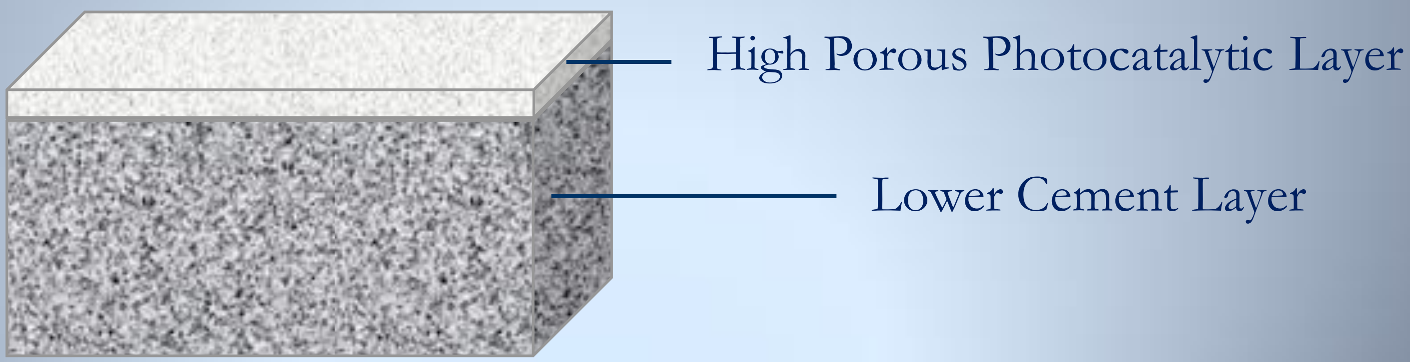
Photocatalytic pavements combining asphalt and cement mortars



Bituminous pavement sprayed with photocatalytic pollutants/emulsions

Photocatalytic Cement Blocks Pavements

PHOTOCATALYTIC CEMENT BLOCK



CASE STUDIES

Roundabout – Palazzolo sull'Oglio (BS)

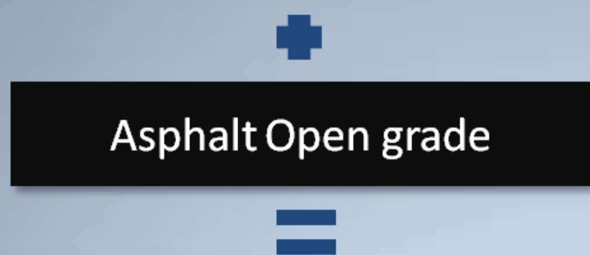
ZONE 30 – Cornaredo (MI)

Via Borgo Palazzo (BG)

Photocatalytic Pavement Combining Asphalt and Cement Mortars

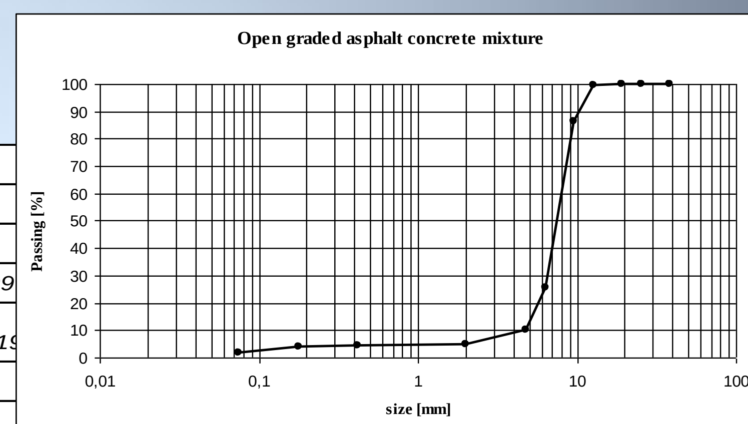
The titanium dioxide is mixed together with the **cement mortar** and poured into the asphalt layer

Photocatalytic cement mortar



Composite Photocatalytic Pavement

Penetration (25°C)	***50-70***	*EN 1426:1999*
Softening point	***46-54 °C***	*EN 1427:1999*
Fraass test	***< -8 °C***	*EN 12593:1999*
Dynamical viscosity (160°C, y=100 s-1)	***< 0,3 Pa s***	*EN 13702-2:1999*
After Rolling Thin Film Oven Tests		*prEN 12607-01:19*
Residual Penetration (25°C)	***> 50%***	*EN 1426:1999*
Softening point increase	***< 11%***	*EN 1427:1999*



Photocatalytic Pavement Combining Asphalt and Cement Mortars

DIFFERENT CONSTRUCTION METHODS

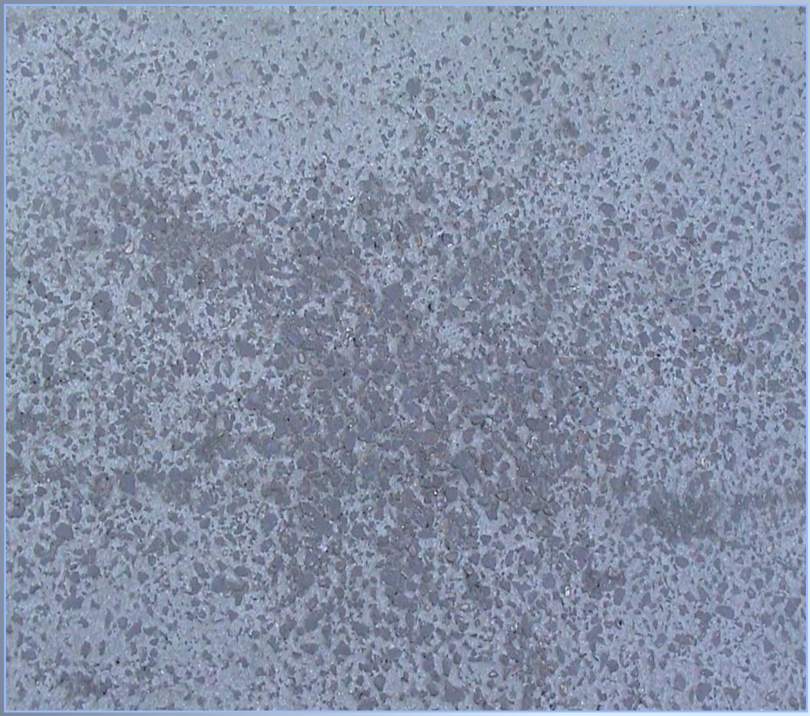
The mortar is applied on t… …urface forming a … coverin…

The m…ar is a…ied on an Op… grade layer, fil… p its …oids for a depth of 1-2…

The mortar is poured into the Open grade layer, filling up all voids for its whole thickness

Photocatalytic Pavement Combining Asphalt and Cement Mortars:

THIN LAYER (PROBLEMS)



CASE STUDIES

BLUE PHOTOCATALYTIC PAVEMENT
Cinisello Balsamo (Milan)

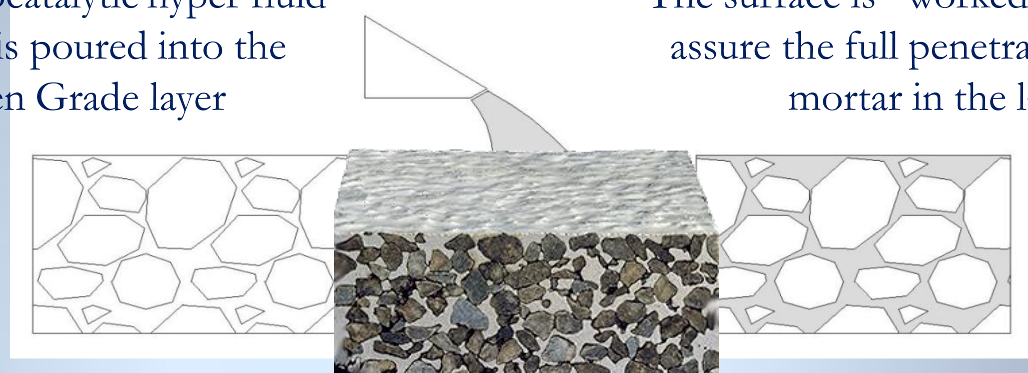
ROUNDABOUT
Milan

Photocatalytic Pavement Combining Asphalt and Cement Mortars

OGAC *(28-30% of voids)* → Hyperfluid cement mortat → Titanium Dioxide *(Anatase)*

The photocatalytic hyper fluid mortar is poured into the Open Grade layer

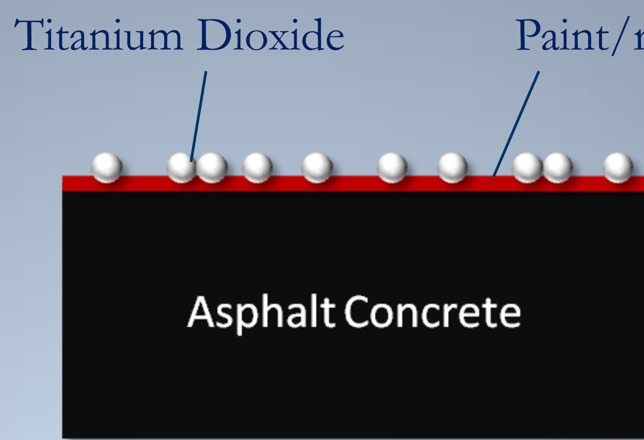
The surface is "worked" in order to assure the full penetration of the mortar in the layer



The result is a composite material combining asphalt and photocatalytic mortar

Bituminous Pavement Sprayed with Photocatalytic

The titanium dioxide is mixed together with the **paint/resin** then sprayed on the asphalt layer surface



LAYING METHODS

- **COLD METHOD** on already existing pavements, new or suitably cleaned

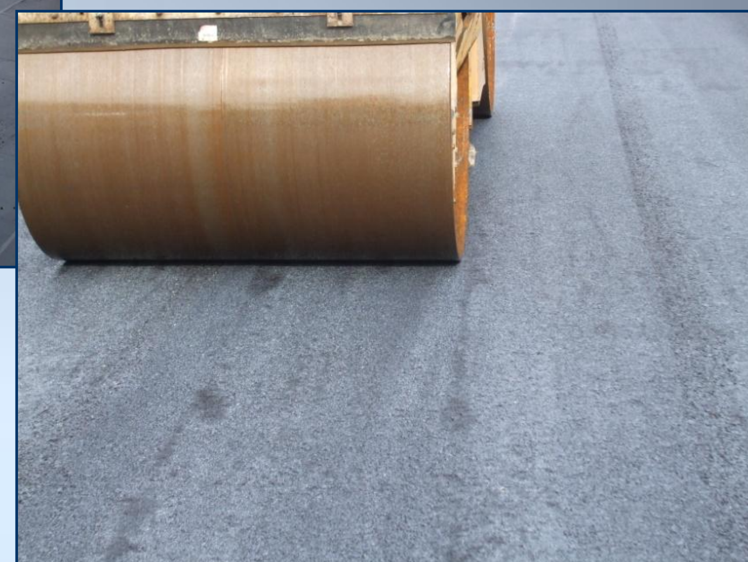
- **HOT METHOD** made directly after the asphalt laying- phase

The two laying methods show:

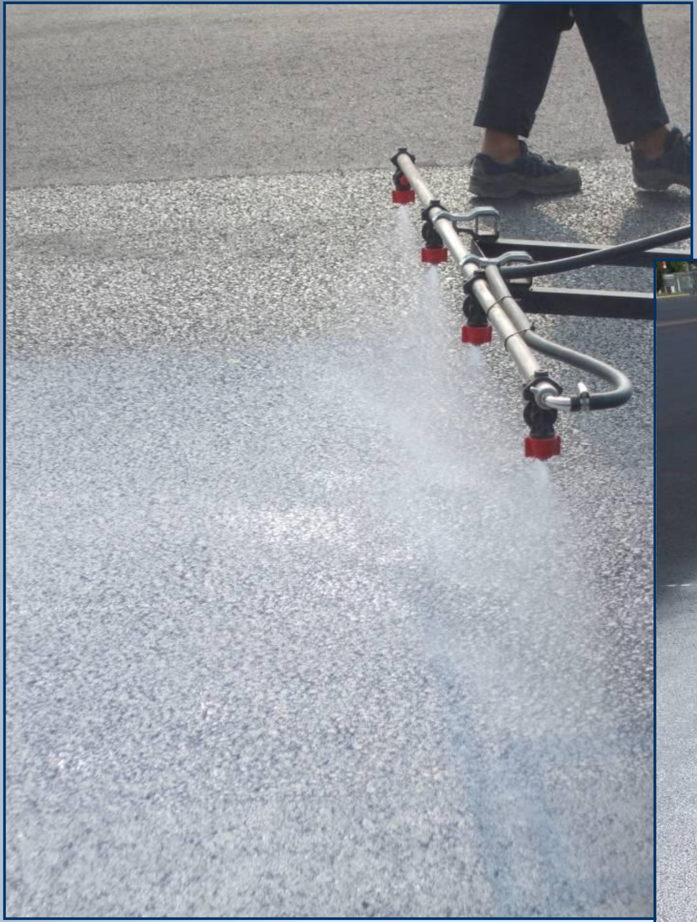
- equal photocatalytic efficiency
- different adherence:
  - cold-method: reduction of 6÷8 BPN
  - hot-method: reduction of 3÷5 BPN

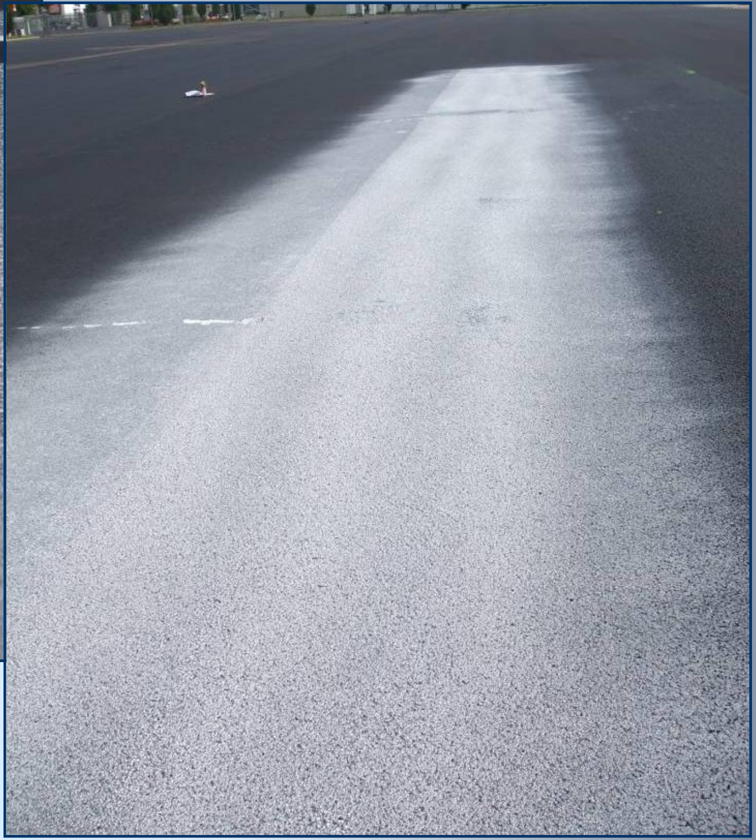
Bituminous Pavement Sprayed with Photocatalytic

"HOT" APPLICATION



"COLD" APPLICATION





Bituminous Pavement Sprayed with Photocatalytic

CASE STUDY 1: Auto-Park in Milan

Area: 4000 m^2

NOx Reduction: 49% *

* Conditions Test: gas flux=1.5 l/min radiant flux=20W/m^2

Bituminous Pavement Sprayed with Photocatalytic

CASE STUDY 2: Highway Forlì-Cesena

Area: 2500 m^2

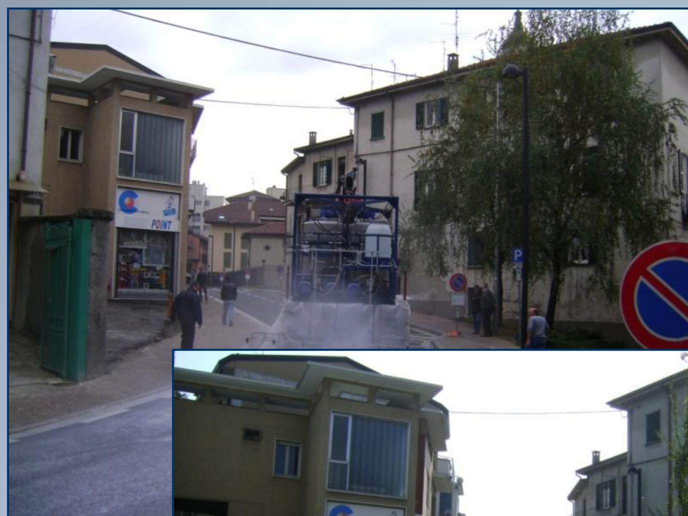
NOx Reduction: 46% *

* Conditions Test: gas flux=1.5 l/min radiant flux=20W/m^2

CASE STUDY 3: Urban Road in Cantù and Monza

GPP: Glass Photocatalytic Pavement

NOx Reduction: 50% *



* Conditions Test: gas flux=1.5 l/min radiant flux=$20 W/m^2$

CASE STUDY 4: Urban Road in Ferrara

Area: 13000 m^2

NOx Reduction: 42% *

* Conditions Test: gas flux=1.5 l/min radiant flux=20W/m^2

CASE STUDY 5: Gallery in Milan

Area: 11000 m^2

NOx Reduction: 46% *

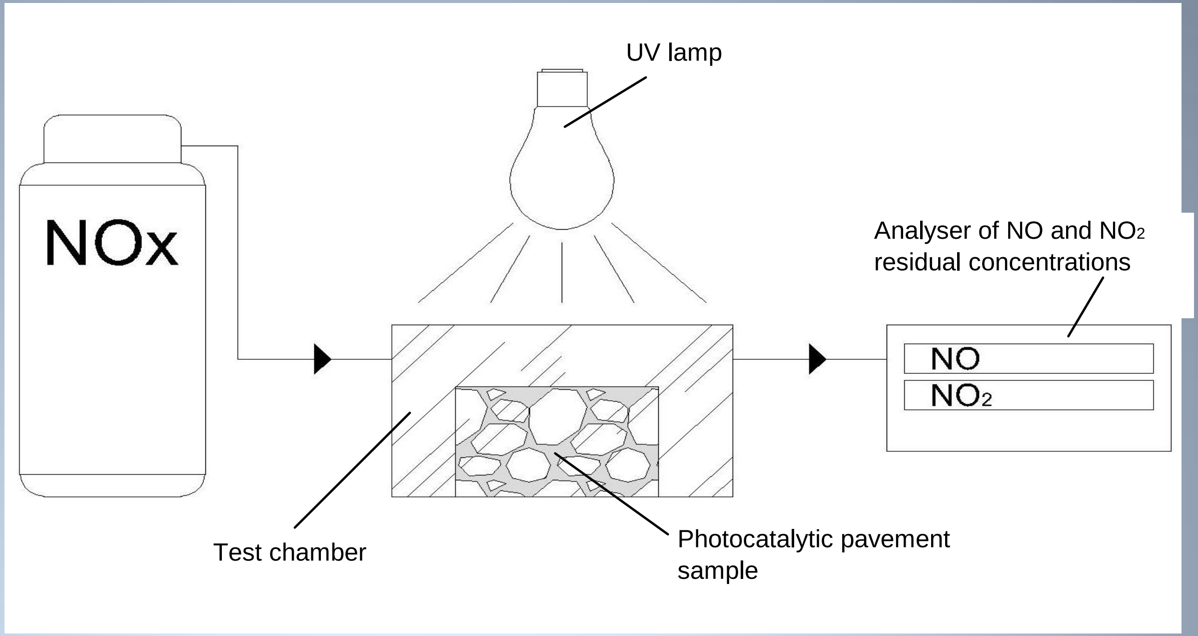
NOx Reduction: 14% **

* Conditions Test: gas flux=1.5 l/min radiant flux=20W/m^2

** Conditions Test: gas flux=5 l/min radiant flux=20W/m^2

EXPERIMENTAL ANALYSIS

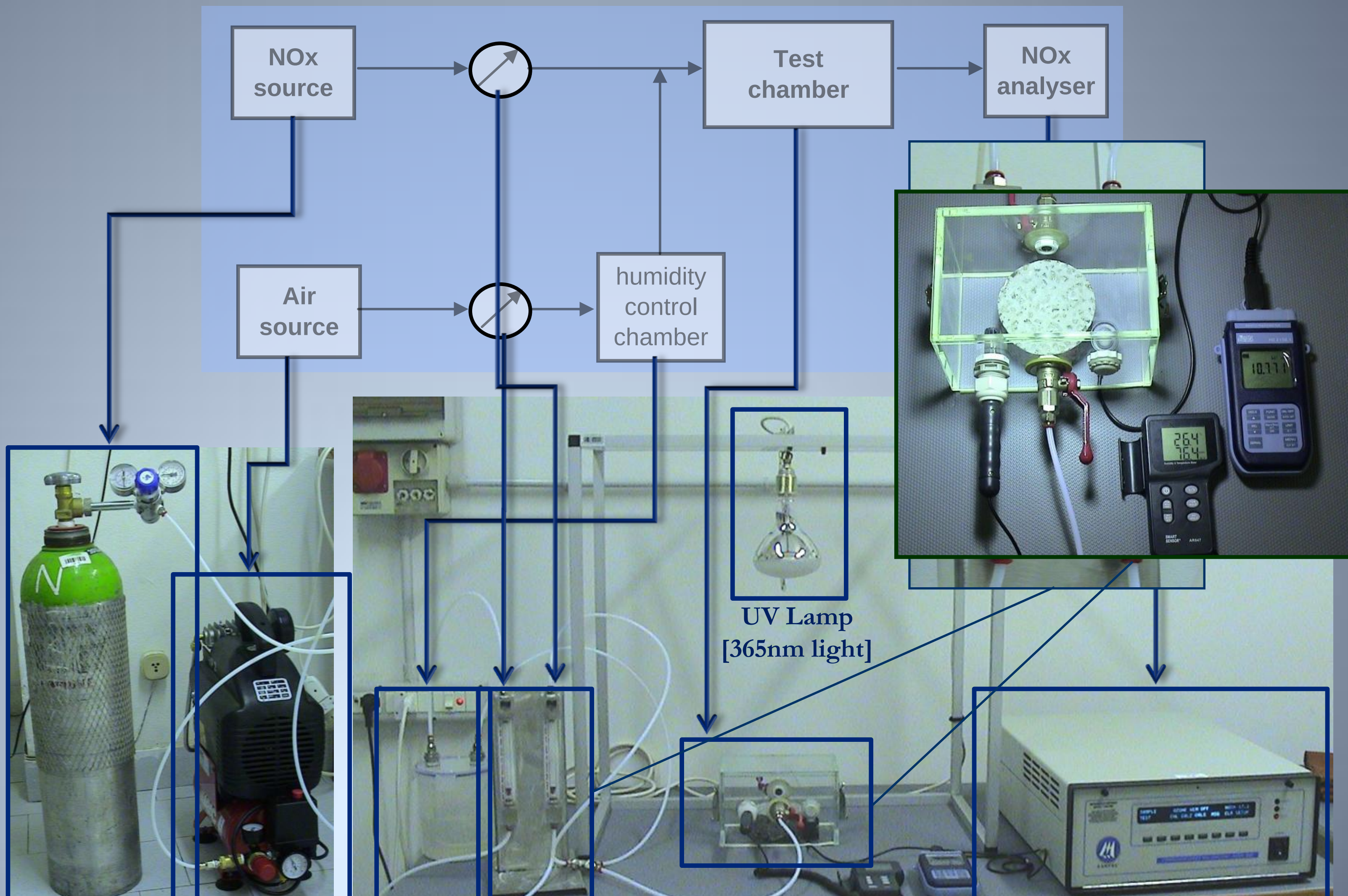
The effectiveness of a photocatalytic pavement in reduction of NO_x concentrations in air was measured through an *ad hoc* test equipment



- A NO_x flow entering into the test chamber
- A UV light simulating sun light
- A chemioluminescence analyser measuring NO_x concentrations into the chamber

Testing Protocol & Laboratory Test

In details



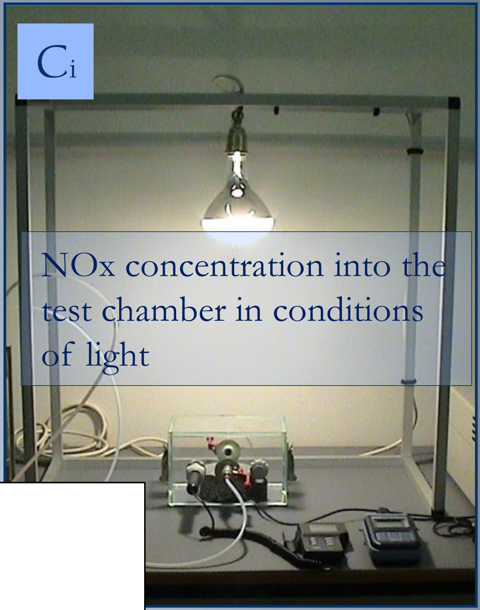
Testing Protocol & Laboratory Test

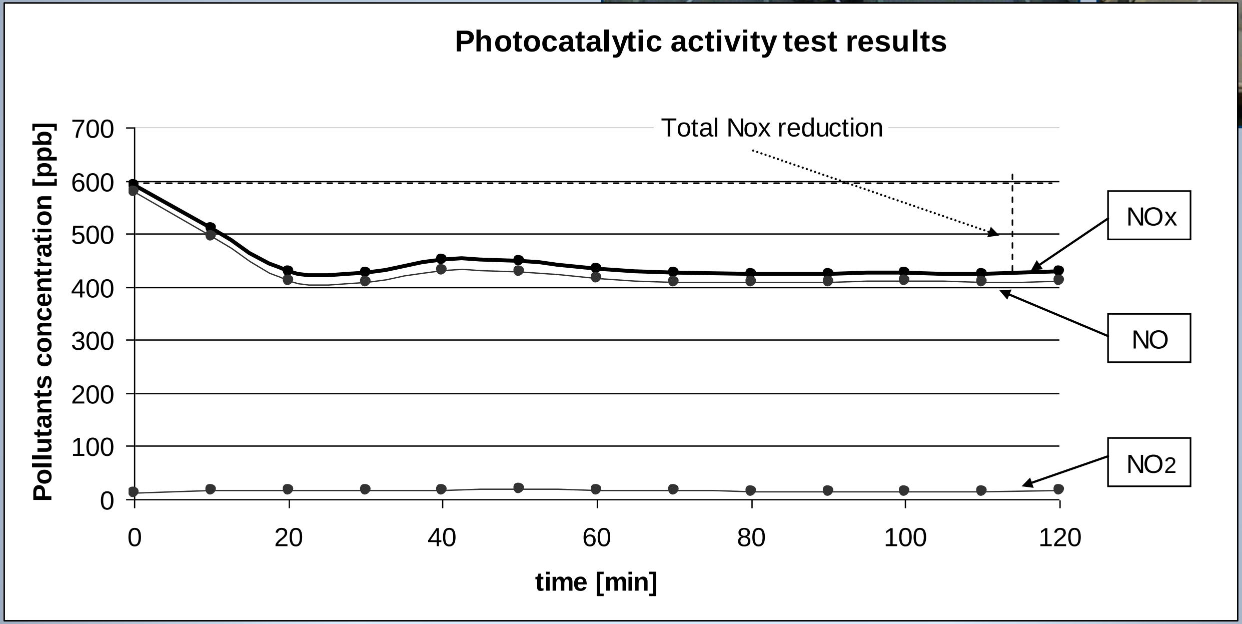
DEGRADATION OF NITROGEN DIOXIDE

- Humidity = 50% ± 5%
- Temperature = 25°C ± 5°C
- Radiant flux = 20 ± 1 W/m²
- Gas flow = 5 ± 0.1 l/min

NO_x reduction [%]

$\Delta C = (Cd - Cs) \times 100 \ / \ Cd$

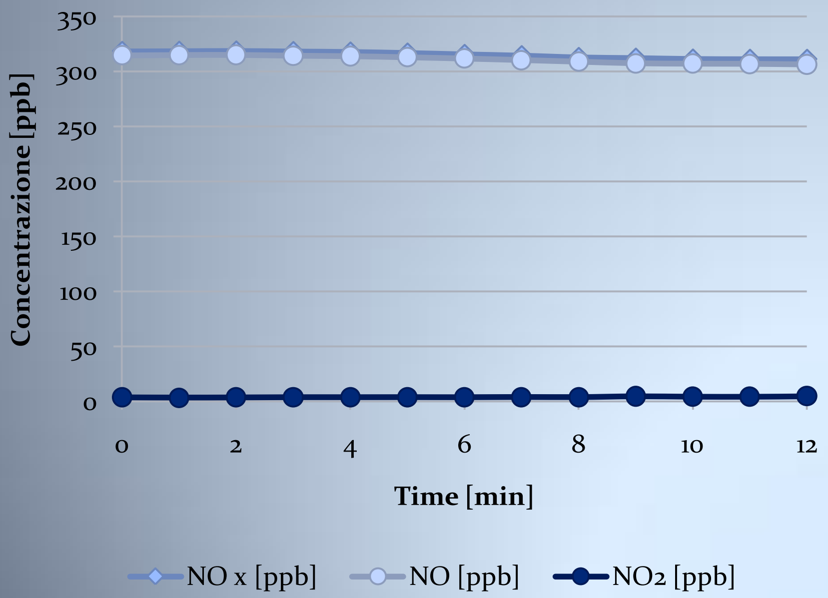




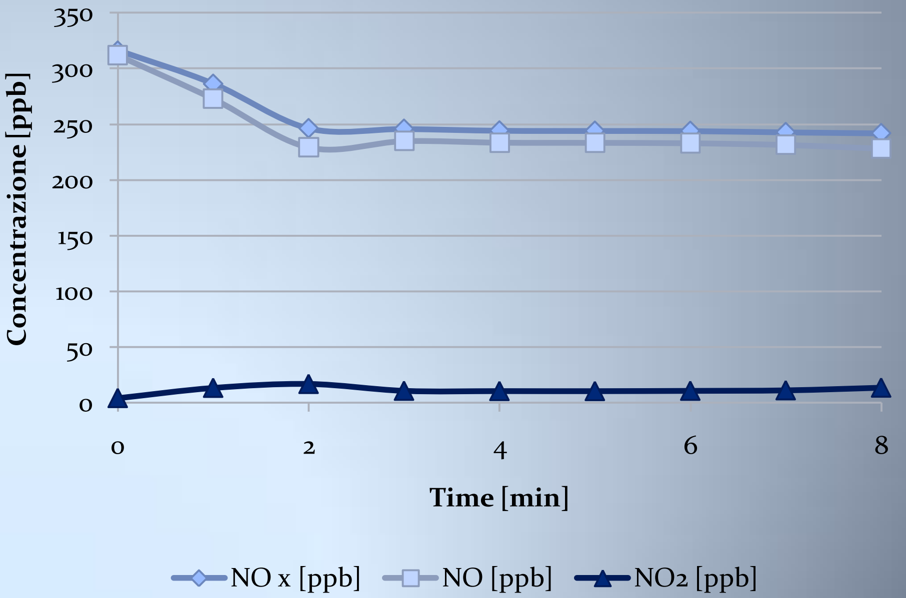
Testing different "photocatalytic" materials

NOx Concentration Abatement :
Sprayed pavements

Material A



Material B

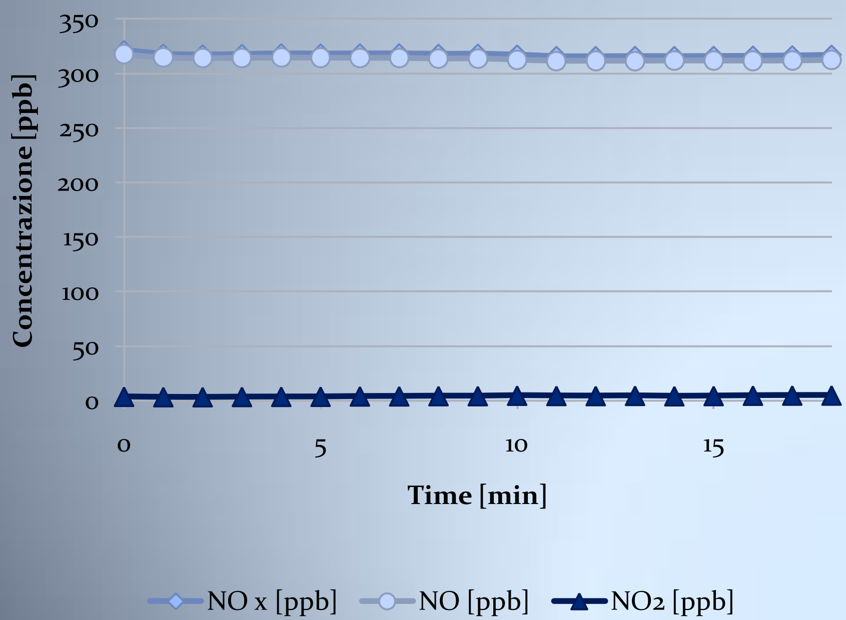


Testing different "photocatalytic" materials

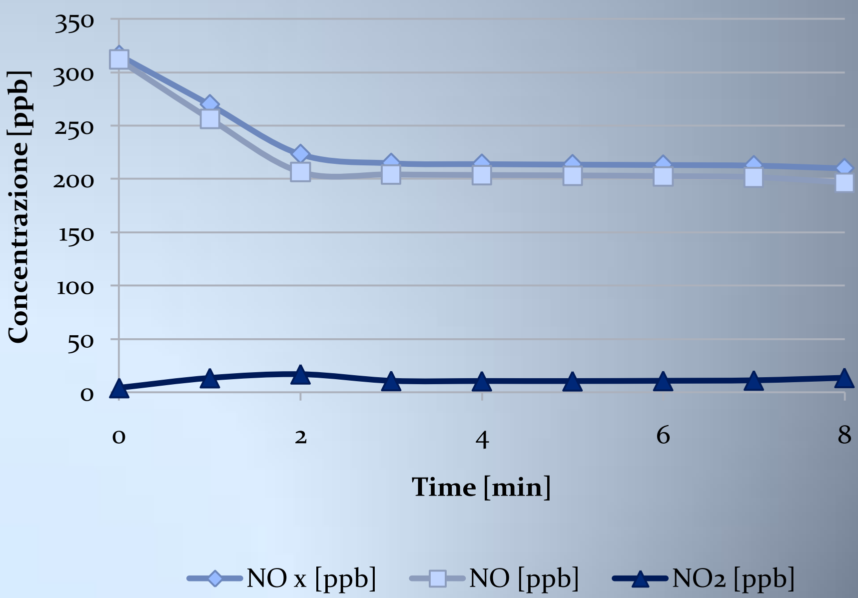
NOx Concentration Abatement :

Sprayed pavements

Material A



Material B



SOME PAPERS

Crispino M., Lambrugo S., "*Surface characteristics and environmental performances of a photocatalytic innovative pavement*", International Conference Road Safety and Simulation **RSS2007**, Roma, Italy, 7-8-9 November 2007.

Crispino M., Lambrugo S., "*An experimental characterization of a photocatalytic mortar for road bituminous pavement*", **International Rilem Symposium on Photocatalysis**, Firenze, Italy, 8-9 October 2007

Crispino M., Lambrugo S., Venturini L., "*A real scale analysis of surface characteristics of a photocatalytic pavement*", **4th International SIIV Congress**, Palermo, Italy, 12-14 September 2007.

Toraldo E., Lambrugo S., *"The optimization of photocatalytic mortars for road pavements*", **4th International Conference Bituminous Mixtures and Pavements**, Thessaloniki, Greece, April 2007

Da Rios G., Lambrugo S., "*Pavimentazioni di supporto ad azioni fotocatalitiche*", Strade&Autostrade, 3, 2007.

Crispino M., Lambrugo S., Bacchi M., "*Photocatalytic Road Pavements: an analysis of structural and functional performance*", **4th International Gulf Conference on Roads, Qatar, 2008**.

Da Rios G., Lambrugo S., Bacchi M., "*Analisi sperimentale per pavimentazioni urbane fotocatalitiche*", Enna, Convegno nazionale **SIIV, 2008**.

Crispino M., Lambrugo S., "*Effectiveness of a photocatalytic wearing course through experimental analysis*", **ISAP 2008, Zurich.**

Da Rios G., Fiori F., Lambrugo S., "*Fotocatalisi per l'ambiente urbano*", Strade&Autostrade, 3, 2008

NEEDS

- International Standards for Laboratory and in site tests
- Certification of photocatalytic materials
- Full scale tests to better understand the influence of photocatalytic surfaces on the whole section
- Improve durability and reducing costs
- Accelerate acceptance and implementation from Road Agencies of **innovation**
- **Support the development at all levels of a "sustainable " culture**

Thank you for your kind attention