F55 & P119 Photocataltic mortar panels based on layered double hydroxides: a study on NOx reduction performance.

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Extended Abstract

Summary

In this work, a field study has been proposed to evaluate the response of various photocatalytic mortars in decontaminating the air from nitrogen oxides. $Ni_3Ti\text{-}CO_3$ and $Zn_2Cr\text{-}CO_3$ layered double hydroxides (LDHs) were synthesized using the coprecipitation method, subsequently characterized, and then incorporated into the mortar. Mortars containing LDHs additives, as well as TiO_2 as reference situation, were fixed onto 2.0 x 0.9 m panels. The photocatalytic panels were installed, together with a meteorological station, in a real environment with high pollution. The concentration of NO_x gases circulating over mortar's surface was monitored in-situ and it is still in evaluation.

Background

Many cities suffer from environmental problems, such as high concentrations of nitrogen oxides in the air, primarily caused by road traffic. To address this challenge, a promising solution involves reducing the concentration of these gases through photocatalytic reactions that transform them into inert compounds ($DeNO_x$ process).

Cement-based materials can be enhanced with photocatalytic properties through the incorporation of photocatalysts during casting, such as TiO_2. However, despite its effectiveness in catalyzing reactions and compatibility with construction materials, TiO_2 has drawbacks such as a high cost, limited DeNOx selectivity, and poor activity in the visible region of the solar spectrum.

In this context, layered double hydroxides stand out. These brucite-type compounds that exhibit outstanding photocatalytic properties can be prepared using simple, low-cost and easily scalable methods [1, 2].

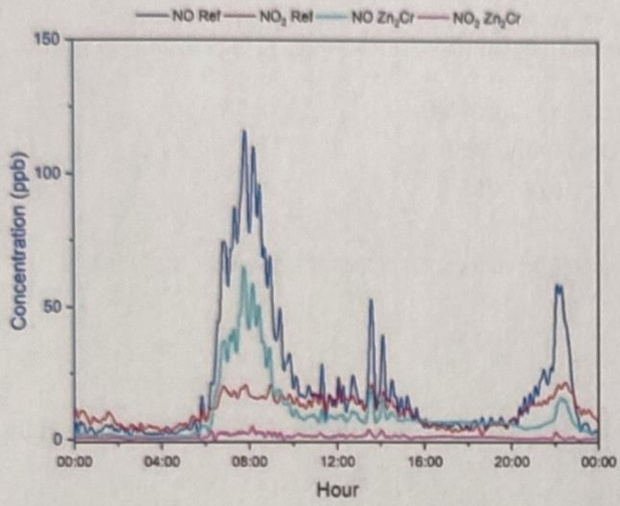
Methodology

The synthesis of both layered double hydroxides employed the coprecipitation method, in which a solution containing metal cations is dropped onto another solution containing the intercalating anion, carbonate for both layered double hydroxides ($Ni_3Ti\text{-}CO_3$ and $Zn_2Cr\text{-}CO_3$). The resulting solid was filtered, initially with distilled water until achieving pH = 7, and then with pure ethanol for the AMOST method, that increases the specific surface area [2]. Then, both products were characterized by XRD, ATR FT-IR, ATG and the De-NOx test, carried out using the ISO 22197-1 standard.

Four panels were prepared: a standard reference panel, another reference of a commercial photocatalytic mortar based on the P25 additive (TiO_2), and two panels incorporating the LDH additives proposed in this research. The mortars were characterized by the same techniques than the additives. The panels were installed on the wall of the sidewalk of a heavy traffic road, along with a meteorological station. Data related to the concentrations of various NO_x gases under study were acquired using two Serinus 40 NOx gases analyser instruments, one of them always measuring the reference, and the other one changing between the other panels.

In the DeNOx tests, the LDHs exhibited elevated conversion values, particularly for $Zn_2Cr\text{-}CO_3$, accompanied by exceptionally high selectivity values as minimal NO_2 is released during the photocatalytic process. Regarding mortars containing LDHs, while the selectivity remains high, the conversion values decrease compared to the LDHs in powder. This is likely attributed to the fewer active sites compared to the pure LDH.

The graph shows a daily profile of the evolution of concentrations for NO and NO_2 gaseous species. Both panels replicate the same NO_x contamination profile, although the concentration values are significantly lower in the photocatalytic mortar-coated panel, confirming its decontamination capacity. The panel not only reduces NO significantly but also the presence of NO_2, a crucial observation considering the high toxicity associated with NO_2 compared to NO. These profiles were monitored for each panel over week-long periods. The acquired data enabled the calculation of gas concentration reduction by comparing various photocatalytic panels with the reference. The analysis considered variations in the environmental conditions, such as temperature, humidity and irradiance.



Graph 1. Concentration profiles of the different gas species over the reference panel and the $Zn_2Cr\text{-}CO_3$ one.

Conclusions

$NiTi\text{-}CO_3$ and $ZnCr\text{-}CO_3$ LDHs were synthesized and applied as photocatalytic additives in mortars. This study reports, for the first time, a field analysis of LDHs-based $DeNO_x$ mortars. Significantly, LDH-based mortars efficiently remove NO_x gases from the air in real urban environments.

Keywords: *Photocatalysts, Mortar, LDH, Titanium Dioxide, De-*NO_x

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References

[1] J. Fragoso, J. Balbuena, M. Cruz-Yusta, I. Pavlovic, M. Sánchez, L. Sánchez, Construction and Building Materials (2023), 394.

[2] A. Pastor, C. Chen, G. de Miguel, F. Martin, M. Cruz-Yusta, J.-C. Buffet, D. O'Hare, I. Pavlovic, L. Sánchez, Chemical Engineering Journal (2022), 429.